7887

7887

HARMSWORTH POPULAR SCIENCE

EDITED BY ARTHUR MEE

***

CONTRIBUTING STAFF

ON THE CONTRIBUTING AND CONSULTING STAFF OF POPULAR SCIENCE ARE

CALEB WILLIAMS SALEEBY
Fellow of the Royal Society of Edinburgh. Doctor of Medicine. Scientific Author, Lecturer at the Royal Institution.

L. G. CHIOZZA MONEY, M.P.
Author and Political Economist.

W. BEACH THOMAS
Journalist and Agricultural Expert.

JOHN DERRY
Journalist and Educationalist.

EDWARD WRIGHT
Writer on Philosophy.

GERALD LEIGHTON
Professor of Pathology and Bacteriology at Edinburgh University.

T. THORNE BAKER
Electrical Expert. Lecturer at the Royal Institution.

H. HAMILTON FYFE
Author and Journalist.

ERNEST A. BRYANT
Author of the Natural History section of the Children's Encyclopædia.

RONALD CAMPBELL MACFIE, M.A.
Author of "Science, Matter, and Immortality."

JOSEPH HORNER
Author of technical works; member of the Institute of Mechanical Engineers.

AND OTHERS

***

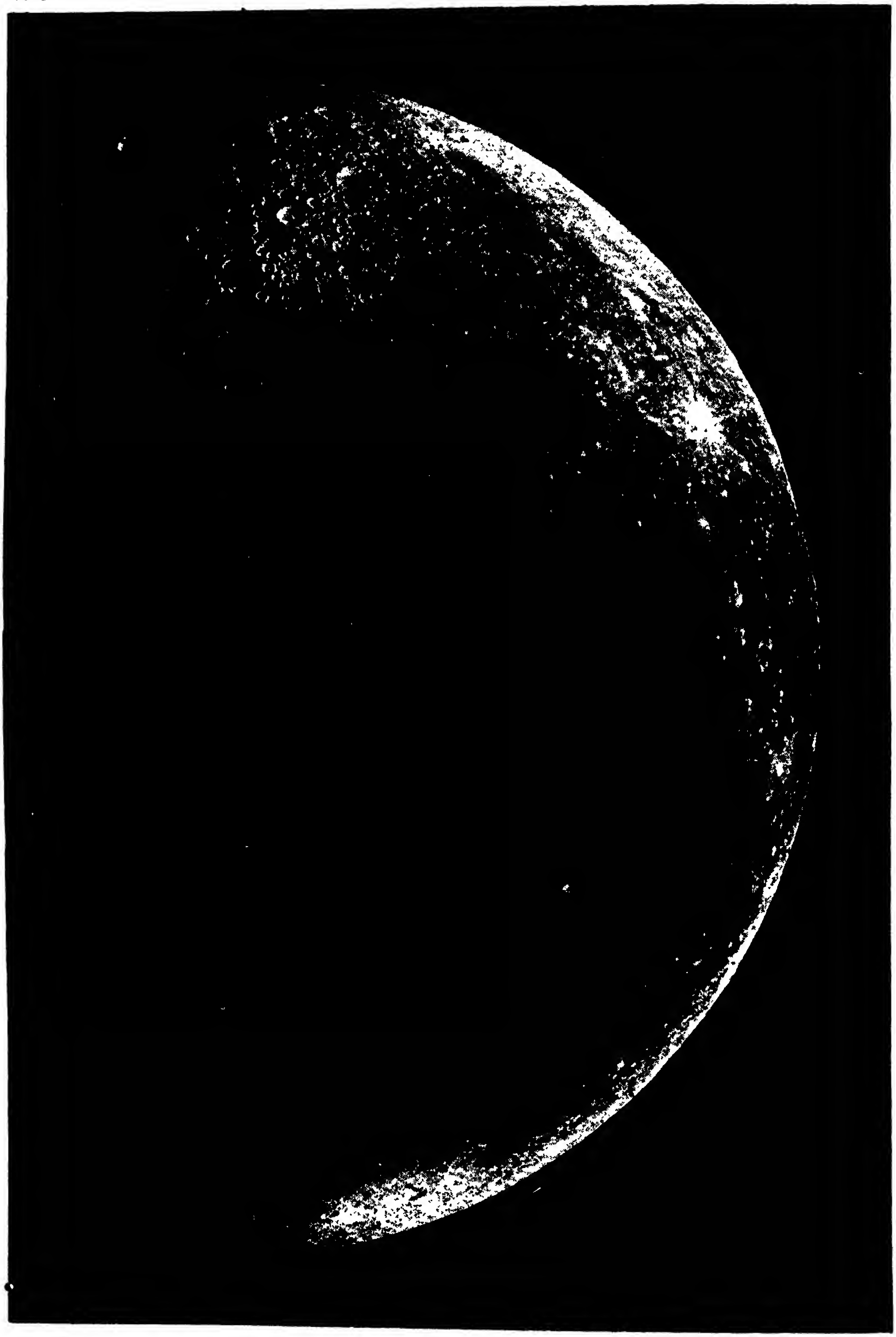
VOLUME FOUR

LONDON:
THE EDUCATIONAL BOOK CO., LTD.
MCMXIII

ꞁN ATHLETE STRUGGLING WITH A PYTHON. BY LORD LEIGHTO꞉

CONTENTS OF VOLUME FOUR

DARK LUNAR SEAS AND SHINING CRATERS



VIEW OF THE MOON WHEN TWENTY DAYS NINETEEN HOURS THROUGH HER MONTHLY CHANGES

From a photograph by M. P. Puiseux at the Paris Observatory

PROBLEMS OF THE MOON

The Neighbour-World We Can See Best, but which Perplexes Us with Unsolved Problems

EARTH'S NEAR NEIGHBOUR IN THE SKIES

FROM the earliest days, the inconstant and mysterious queen of night has been viewed with awe and wonder. How strange she is to the primitive eye and mind! To the unaided vision there is nothing else like her in the heavens, nothing to compare with her for variety of aspect. She emerges from the invisible as a delicate sickle of light in the west, within which, as twilight deepens, the ghost of the old moon is shadowed forth. Daily she grows as a crescent until half her disc is illumined; daily she grows on in humped or gibbous form until full moon, a fortnight from her birth; then, during another fortnight, she dwindles again to nothingness. Doubtless the moon has been supposed by all primitive peoples to be a celestial body which actually grows and diminishes throughout this period of a month. The connection between her phases and the changes of the tide could not escape the notice of dwellers by the shore. No wonder the month, and the week, or quarter of the month, were, after the day, the earliest divisions of time.

But the moon has other mysterious qualities which also distinguish her from the host of heaven. Daily she is found to have changed her place among the stars; daily she rises and sets later than on the day before. Again, of all the heavenly bodies, only the moon is visible both by day and by night. Her brilliant disc, when full and high in the heavens, is sometimes notably larger and sometimes smaller. Her face bears some elusive design in dark and light—the man in the moon, variously interpreted by different peoples. Innumerable superstitions cluster about the moon; she has been answerable chiefly for disasters and afflictions, such as blindness and insanity; indeed, the very word "lunacy" is derived from her Latin name. But we need only look upon a moonlit scene to understand the universal hold the moon has had upon human imagination; there is an enchantment or glamour in her radiance which none can wholly escape. For all these reasons the moon was the earliest subject of astronomical study, and the ancient Chaldæans had penetrated deeply into the secrets of her movements.

To the modern astronomer, also, the moon remains an object of extraordinary interest. She is by far the largest satellite of any in the solar system, in proportion to the planet about which the satellite revolves. Her movements, which gave Sir Isaac Newton the final proof of his theory of gravitation, still offer mathematical problems of great complexity. The character of the moon's surface, though mapped and photographed in great detail, is to this day full of unsolved questions. Thus, the origin of those circular structures known as craters, volcanoes, or vulcanoids, present in thousands over the face of the moon, is not yet fully understood; the large, smooth areas called seas, or in Latin "maria," still await explanation; and the nature of the bright bands which radiate from certain points over vast distances is even more obscure.

Until not very long ago it was thought to have been proved that the moon has no atmosphere; it is now certain that there is an atmosphere of some kind, though its nature and extent remain to be determined. But before studying the moon's surface and its problems let us consider the chief facts with regard to her size, shape, distance, and movements.

So far as can be determined by observation and measurements, the moon appears to be a perfect sphere, not flattened like the earth at the Poles. From theoretical considerations it is believed, however, that the moon differs from a true sphere in two

respects—namely, that she is slightly flattened at the Poles, and that she is slightly elongated in the direction from the moon to the earth. The diameter of the moon is nearly 2160 miles, or rather more than one-fourth of the earth's diameter. Her superficial area is rather more than one-fourteenth of the earth's surface, and her volume is about one-forty-ninth of the earth's volume. The density of the moon is to the density of the earth as 61 to 100; that is to say, on the whole the moon consists of materials which are lighter, in that proportion, than the materials of which the earth on the whole consists. As compared with the density of water, the mean density of the earth is as 5·7 to 1, and the mean density of the moon is as 3·5 to 1. As the moon is so much less dense than the earth, her mass bears a much smaller proportion to the earth's mass than the volume of the moon bears to the volume of the earth; so that the mass of the moon, or her total gravitative force, is less than one-eightieth of that of the earth. The gravity at the surface of the moon is one-sixth of the gravity at the surface of the earth; so that an object suspended on a spring balance, and weighing six pounds on earth, would weigh only one pound on the moon.

The Relation Between the Moon's Distance from the Earth and Her Size

The moon's distance from the earth varies according to her position in an elliptical and eccentric orbit. At her nearest point to the earth the moon is 221,614 miles away; at the furthest point she is 252,972 miles away; and the mean distance is 238,818 miles, or rather more than thirty times the earth's diameter. So, if the earth were represented by a ball one inch in diameter, the moon would be represented by a pea thirty inches away. Owing to her varying distance from the earth, the apparent diameter of the moon varies from 33′ 30″ when she is nearest to 29′ 21″ when she is furthest. The change in the apparent size of the moon may be illustrated by the fact that a halfpenny, being one inch in diameter, placed 8 feet 5 inches away from the eye, would exactly cover the moon when at her nearest; and the same coin placed 9 feet 11 inches away from the eye would exactly cover the moon at her furthest point.

Owing to her motion in her orbit round the earth, which she completes in about 27⅓ days, the moon is found on each successive night to have shifted eastward among the stars, so that she comes to the meridian about 51 minutes later every day. Yet, though the moon completes her orbit in about 27⅓ days, the month, or "lunation," from new moon to new moon is longer than this period of the completed orbit, and amounts to about 29½ days. Inasmuch as the month, completing the changes in aspect of the moon, depends upon her movement in her orbit, this discrepancy between the 29½ days of the month and the 27⅓ days of the journey round the earth requires explanation. It is due to the earth's annual movement round the sun, whereby the sun, like the moon, apparently shifts daily eastward relatively to the earth. In this eastward revolution of the two bodies relatively to the earth, the moon, performing in about 27⅓ days a circuit which the sun takes about 365¼ days to perform, frequently overtakes the sun and passes him.

The Variation Between the Orbits Round the Sun of the Earth and the Moon

The moment when the moon thus overtakes the sun is new moon, and a month is the interval from one new moon to the next. The month is longer than the period of the moon's revolution round the earth, because the sun has moved eastward while the moon is performing this revolution.

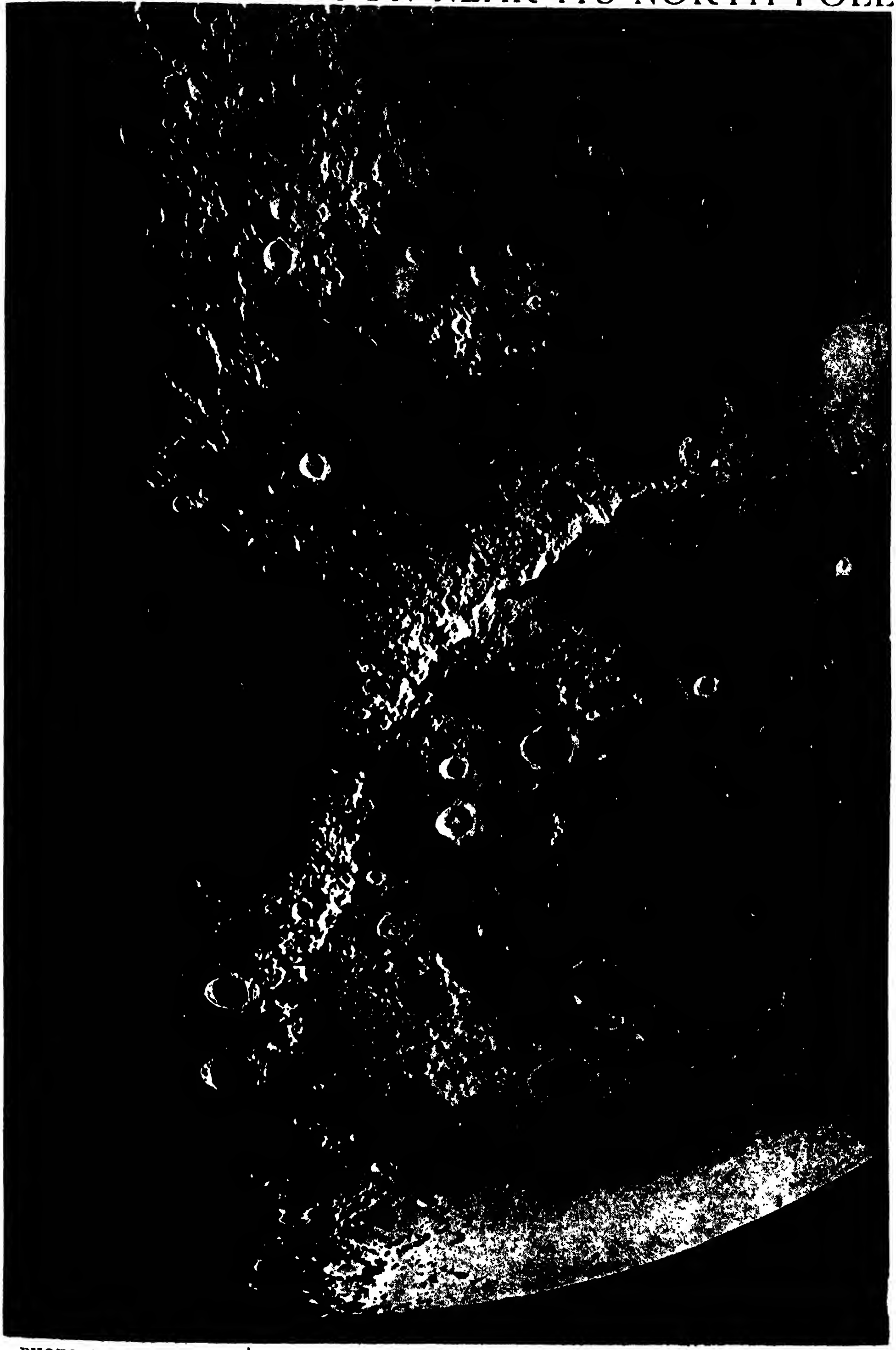
Throughout her orbit, the moon follows a line of varying curve, which is always concave, and never convex, towards the sun. If the earth's orbit be drawn on a sheet of paper as an ellipse round the sun, the moon's orbit round the sun will be represented by a line swaying very slightly from side to side of that ellipse. Her position at new moon is inside, and at full moon outside, the ellipse of the earth's orbit; and her path crosses the earth's orbit at the first and third quarters of the moon.

The Moon and the Earth with the Same Centre of Gravity

In her orbit round the earth, the moon travels at the rate of 2100 miles an hour. It is not precisely accurate to speak of the moon's revolution round the earth as if the earth had no share in that movement; actually, they both revolve round their common centre of gravity, but that common centre of gravity is 1100 miles below the earth's surface. The plane of the moon's orbit is slightly inclined to the ecliptic.

At new moon, the moon is said to be "in conjunction"; at full moon, "in opposition"; and when the lines between moon and earth, and earth and sun, form a right angle, the moon is said to be "in quadrature." The "elongation" of the moon is a term applied to the angle between these

PART OF THE MOON NEAR ITS NORTH POLE



PHOTOGRAPH OF A PART OF THE MOON WHEN ABOUT TWENTY AND A HALF DAYS OLD
Photographs, drawings, and maps of the moon's surface represent it as seen in a telescope—upside down. Thus the North Pole of the moon is at the bottom of this page. All the features described in these pages may be identified in this photograph, taken by Mr. G. E. Hale at the Mount Wilson Observatory—illuminated mountains, rugged ranges, valleys, seas, craters, and radiating systems of bright rays.

two lines—earth to moon and earth to sun; in other words, the elongation of the moon is the angular distance of the moon from the sun.

One half of the moon's globe—namely, the hemisphere which is at any moment towards the sun—is illumined; and the aspect of the moon as seen from the earth depends upon the amount which we are in a position to see of this illumined hemisphere.

The Varying Amounts of the Moon that We Can See

Thus, if we can only see the edge of the bright hemisphere, the moon is a crescent; and this crescent grows to half moon, and finally to full moon, in proportion as we are able to see more, and finally all, of that half of the moon which is opposite to the sun. The line separating the illumined portion of the moon from the dark and invisible portion is called the terminator. This is the position of sunrise or sunset upon the moon's surface; and because of the great inequalities of that surface, due to mountains and craters, the terminator is a very ragged line, as may be seen with a glass of low power. The terminator is always a semi-circle, but from the terrestrial point of view is a semi-circle seen more or less obliquely, and is therefore usually a semi-ellipse. Except at full moon, when the aspect of the moon is circular, and at half moon, when the terminator is a straight line, the visible bright surface of the moon is always bounded on one side by a semi-circle and on the other side by a semi-ellipse. As she travels in her orbit about the earth the moon always turns the same portion of her surface toward our vision. The other side of the moon has never been seen by man, and has consequently been made the subject of the most fantastic conjectures.

Why the Moon Keeps the Same Face Towards Us Always

The moon keeps the same face toward the earth because she rotates once on her own axis in precisely the same time which she takes to revolve once round the earth. Perhaps it is simpler to say that relatively to the earth she does not rotate at all. At any place on her surface, the day lasts for a fortnight and is followed by night, lasting for a fortnight also. This exact agreement between the period of the moon's rotation on her own axis, and the period of her orbital revolution, is of course not accidental. It is supposed to have been brought about by the action of the earth's gravitation on fluid or semi-fluid constituents of the moon. Tides act mechanically, by means of their friction, like a brake. There is no doubt that the tides which the moon and sun hold up in the oceans of earth are acting as a brake upon the earth's daily revolution, and must in the long run, though very slowly, have the effect of lengthening the earth's day. But the earth's gravitational force is vastly greater than that of the moon; and in remote times, when the moon had not yet been cooled throughout to solid consistency, and still contained large proportions of viscous materials such as molten lava, the retarding effect of the tides which the earth raised upon the moon may well have brought the moon, in the course of ages, to a fixed position relatively to the earth. To the same tidal action is supposed to be due that slight lengthening of the moon's diameter in the direction of the earth which is believed to be the means of keeping her with the same face always turned toward the earth.

The Little Portion of the Other Side of the Moon which We Sometimes See

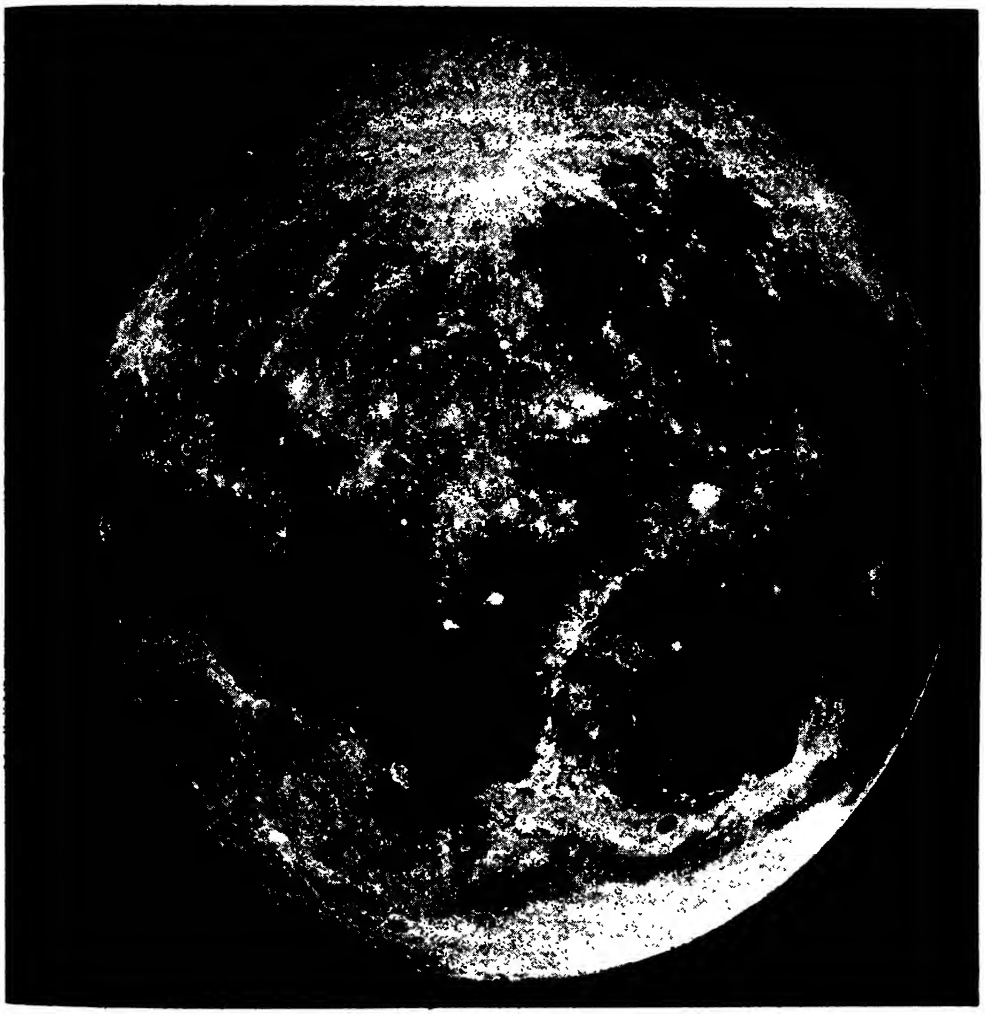
Owing, however, to the relative positions of the two bodies, and to certain movements named "librations," which are too complex to be described here, the dwellers on the earth are able from time to time to see a slightly varying face of the moon. Therefore, though we can never see at any one time more than half of the moon's globe, we can see in the long run somewhat more than half. Slightly more than one-sixth of the area of the hidden hemisphere is in one way and another revealed. More exactly, 41 per cent. of the moon's surface is always visible at full moon; another 41 per cent. of her surface is never seen under any circumstances; and the remaining 18 per cent. is sometimes visible and sometimes invisible.

These glimpses of the other side of the moon show us the craters and other structures in a highly foreshortened position, but they are sufficient to prove that, so far as we can tell, the surface features of the hidden aspect of the moon are similar to the features of the hemisphere which is fully visible. They give no support to those theories which would establish, on the surface of the moon remote from the earth, conditions suitable for the existence of organic life. To the utmost verge of observation everything shows the same stupendous desolation.

The appearance commonly known as the "old moon in the new moon's arms" is due to illumination of the surface of the moon by sunlight reflected from the earth. Of course, the earth shines upon the moon

just as the moon shines upon the earth, but the earthshine, as it is called, is much stronger than moonshine. To judge from the comparative size of the two globes, the light reflected from the earth should be about thirteen times as powerful as the light from the moon; but we must also take into account the fact that the earth's reflective power, owing to her seas and snows, is greater than that of the moon, so that earthshine may probably be regarded as nearly twenty times as strong as moonshine. The ruddy colour of earthshine, as it is seen when reflected back to us from the moon, is due to the fact that the sunlight which thus ultimately comes to us has passed no less than three times through the earth's atmosphere. The ruddy light of the setting sun, which must obviously pass through a thicker layer of the atmosphere than the light of noontide has to traverse, is evidence that the atmosphere absorbs light of other colours in greater proportions than it absorbs red light.

The full moon, especially in her northern hemisphere, is much darker in some parts than in others, but the greater part of her face is bright. Yet, though she appears so brilliant in the nocturnal sky, the moon is not really a very good reflector; her apparent brightness is due chiefly to contrast with the dark sky. When seen in full daylight, her gleam is faint compared to that of the whitest clouds. Indeed, her light has been shown to be little more than one-sixth of that which would be reflected, in sunlight,



OUR VIEW OF THE MOON AT THE AGE OF FOURTEEN DAYS AND EIGHT HOURS

From a photograph taken by Messrs. E. S. Holden and J. M. Schaeberle at the Lick Observatory, United States.

by a perfectly white disc of the same size. The brightness of the moon's surface is much the same as that of sandstone rocks illumined by the sun. "I have frequently," said Sir John Herschel, "compared the moon setting behind the grey perpendicular façade of the Table Mountain, illuminated by the sun just risen in the opposite quarter of the horizon, when it has been scarcely distinguishable in brightness from the rock in contact with it." The proportion which the light of the full moon bears to the light of the sun is about 1 to 618,000. Elaborate calculations, based upon the comparative illumination given by the moon in her several phases, have shown that she reflects more light, when full, than she could reflect if her surface were smooth. It is evident to the eye that the full moon is as bright towards the edge of her disc as in the middle; but, inasmuch as she is a sphere, her outer parts would shine less brilliantly than the centre if she were not rugged. From the above-mentioned calculations it appears that the inequalities upon the moon's surface slope, on the average, at an angle of 52 degrees. This is a very much greater average steepness than is found upon earth, and is due to the absence of water, which planes down terrestrial inequalities.

The Extraordinary Distinctness with which We See the Details of the Moon's Surface

As we shall see later, there are great differences in brightness within the bright parts of the moon, and there are features which increase remarkably in brightness as the sunlight falls on them more vertically. The most powerful existing telescopes show the moon very much as we should see her surface with unaided vision at a distance of forty miles. The terrestrial atmosphere, and especially the moisture it contains, form the chief obstacle to distant vision along the earth's surface, and so make mountains very dim and indistinct at forty miles. But the line of sight toward the moon passes through a far thinner atmospheric screen, so that we may compare the forty-mile view of the moon with a thirty-mile, or perhaps even a twenty-mile, view of a terrestrial landscape. The amount of detail which can be seen clearly is surprising. "Seen with the greater telescopes," says Professor Shaler, "the surface of the moon may reveal to able observers, in the rare moments of the best seeing, circular objects, such as pits, which are perhaps not more than five hundred feet in diameter. Elevations of much less height may be detected by their shadows, which, because there is no trace of an atmosphere on the moon, are extraordinarily sharp, the line between the dark and light being as distinct as though drawn by a ruler. Elongate objects, such as rifts or crevices in the surface, because of their length, may be visible even when they are only a few score feet in width, for the same reason that, while a black dot on the wall may not make any impression on the eye, a line no wider than the dot can be readily perceived." Under such circumstances the principal features of London—the river, parks, squares, and perhaps some of the streets—could be clearly distinguished.

The Argument in Favour of the Absence of Atmosphere Round the Moon

The question with regard to the moon's atmosphere is beset with contradictory evidence, and it is not yet possible to come to a satisfactory conclusion in the matter. In the first place, those who deny that the moon has any atmosphere can make out a very strong case. The absence of atmosphere is inferred, as we have just seen, from the excessive sharpness of the shadows, showing that there is not any such diffusion of sunlight as must be produced by a gaseous medium. Since our bright sky and our twilight are due to the diffusion of light in the atmosphere, the sun as seen from the moon must shine in a black sky, and black night must follow immediately upon the moon's sunset, if there is no atmosphere. Certainly the appearance of the moon's surface, as seen with a powerful telescope, favours this view.

The shadows are as sharp as those which are thrown by an electric arc. The terminator, or line of sunset, though very uneven, is absolutely definite, so that the areas through which it happens to pass are quite bright or quite dark, and pass from brightness to darkness without any intermediate shade.

The Argument for an Atmosphere of Some Kind

Further, it has been observed times without number that when a star passes behind the moon, its light shines steadily, and is neither displaced nor obscured, nor altered in colour, until the very moment when it suddenly disappears, being occulted by the advancing globe of the moon; and it has been argued that if there were any atmosphere round that globe it would certainly affect the star's light. On the other hand, we have undeniable evidence to precisely the contrary effect. A twilight prolonging the cusps of the crescent moon has been observed. Again, in total eclipse of the sun, the coal-black

body of the moon, which covers his disc like a screen and is surrounded by the bright glory of the corona, does not appear in the least like a black disc, but is vividly seen to be globular; and this effect can hardly be explained except by the diffusion of sunlight through an atmosphere of some kind on the moon, so as to bring the sunlight somewhat round the moon's edge. the planet's light; and it has therefore been suggested that the moon's atmosphere, whatever it may be, is condensed and disappears on that part of the moon which is at any time in frigid night. But when the illumined edge of the moon occults a bright planet, such as Jupiter, a dark band, parallel to the moon's edge, is thrown across the planet. That this dark

THE ENORMOUS CRATER OF COPERNICUS, FIFTY MILES IN DIAMETER, ON THE MOON
From a photograph by Mr. G. W. Ritchey at the Yerkes Observatory

Even the proof of the absence of lunar atmosphere, which is based on the appearance of stars at the moment of their occultation, is met by perfectly definite observations, and even photographs, showing various modifications of the light of planets as they approach and pass behind the edge of the moon. Occultation by the dark limb of the moon does not appear to affect band is no effect of contrast, or other subjective impression, has been proved by photographs which show it very clearly.

Again, during the occultation of Mars on December 4, 1911, Professor Luther, of Düsseldorf, observed that the half of the planet's disc which was nearest to the edge of the moon became green, as if it were overcast by a shadow, although the outer

half of the planet remained as bright as usual. Consulting his notes of previous observations, he found that he had witnessed a similar change some years previously; and he has come to the conclusion that there exists some material, extending to at least sixty miles above the surface of the moon, capable of absorbing or otherwise modifying the light proceeding from a body which is passing behind it.

The Great Differences Between the Moon's Atmosphere and that of the Earth

Observations such as these make it impossible any longer to say that the moon has no atmosphere at all, or practically no atmosphere, as was generally believed until recent years; but they do not in any way affect the certainty that her atmosphere is far less dense than that of the earth. The chief consequence of the extreme tenuity of the moon's atmosphere is that the sun's heat which falls upon her surface must radiate away again with extreme facility. The earth's atmosphere, and still more the clouds and moisture it contains, form a very effective blanket, enabling the earth's surface to retain during the winter the heat it has received during the summer, or to retain by night the heat it has received by day. The moon has no sufficient medium to retain the heat; and there is little doubt that during her two-weeks' night her surface must descend to a temperature very nearly as low as that of the unimaginable frigidity of outer space.

Different opinions have been held as to the temperature attained by the moon's surface during her two-weeks' day. On the one hand, the absence of an atmospheric blanket must permit the sun's heat to fall on her desolate rocks with a fierceness quite unknown on earth. On the other hand, the heat she receives so freely is just as free to radiate away again at once.

Heat and Cold as They would be Felt on the Moon

Experiments have been made to estimate the amount of heat the moon thus radiates to the earth. They are necessarily very delicate and have given most contradictory results. But on the whole the evidence seems to be that the temperature of the moon's surface remains very low even when the sun's rays are pouring vertically upon it; probably it never rises to the degree at which ice melts. On the other hand, certain experiments have appeared to show that the temperature of the lunar surface by day far exceeds that of boiling water. Whether the moon be absolutely waterless or not, there is certainly no water in those geographical forms in which we are accustomed to see it on earth. The smooth surface of rivers, lakes, or seas would shine with great brilliancy in contrast with the dull, rocky surfaces around them, and could not escape notice. Those smooth areas which long ago received the name of seas are supposed to be vast plains of solid lava. If there be any water on the moon, it is probably in the form of ice. A few capable observers have described fine clouds floating here and there above the moon, but others as capable have failed to see them. There are no clouds at all comparable to those of the earth, nor is there an atmosphere sufficient to support them. In view of the comparative absence of air and water from the moon, as well as the extreme cold of the lunar night, it is unlikely that her surface is inhabited by living things, even of the lowest order.

Craters—the Most Characteristic Feature of the Moon's Surface

If the moon be viewed with a telescope of moderate power, the objects which first attract attention are the craters. These appear as innumerable circular pits, varying greatly in diameter, thickly scattered over much of the moon's surface. By far the greater number of these pits are surrounded by elevated walls, usually forming perfect rings or circles, with a very steep slope into the pit and a comparatively gentle slope on the outer side of the ring wall. The craters vary in depth, but in almost all the depth is very considerable. The floor is flat, and generally has at its centre a rough cone, or sometimes a second, smaller pit. The larger craters, which may exceed a hundred miles in diameter, often contain on their floors several or even many smaller craters. These larger craters are comparatively few, for these structures increase in number as their size diminishes; and though pits of the diameter of five hundred feet or more may be seen by the best telescopes, there are doubtless innumerable others which are too small for the finest astronomical vision yet obtained. These craters are the most characteristic feature of the moon's surface.

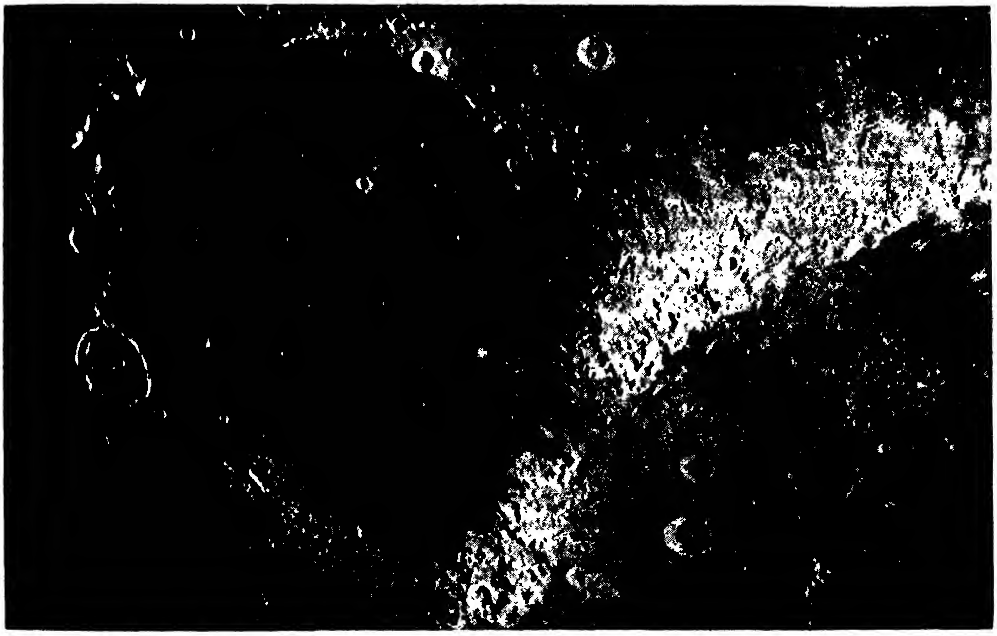
Though various other ingenious theories have been advanced with regard to the origin of the lunar craters, there is little doubt that they were produced in remote ages by processes somewhat similar to those which have thrown up volcanoes on the surface of the earth. The traces of various levels at which the cooling lava has stood, as it gradually subsided, are seen in terraces

that are very evident on the interior of the walls of many of the larger craters; and in some instances the lava is seen to have broken through the ring and to have flowed in streams down the outside of the walls. The numerous cases in which smaller craters are found on the floor of larger ones, and others where new craters have intersected the walls of those already existing, show that the forces which created these pits worked at first on a large scale, and then gradually on a smaller and smaller scale. The largest pits were the earliest and the smallest the latest to be formed. Though evidences of present volcanic activity in the moon have been brought forward, it is more likely that her globe was dead and cold long ages ago.

Next we notice the seas, or "maria," which are chiefly north of the equator. These, because of their comparatively level surface, were formerly supposed to be covered by water. They are vast plains, somewhat depressed below the general level of the moon's surface, and together constitute a third of the hemisphere that is turned towards the earth. Their dark expanses, though remarkably level on the whole, are much broken by slight unevennesses. Except where these seas, or rather plains, have smoothed large areas of the moon, her surface is mountainous and precipitous in an extraordinary degree. These are not like terrestrial mountains, either in form or in arrangement, but constitute rather a huge, ragged confusion. For in the moon there is neither the system of continents, with their clearly marked ranges of mountains, familiar to us on earth; nor has water been at work to smooth the contours and plane away the steepness of the lunar elevations.

The rills, or valleys as they are called when of greater width, are another important feature of the moon. They are cracks or crevices in the lunar surface, so deep as often to appear bottomless. Their walls are steep, or even vertical, and their bases, when seen, contain many craters. The rills are very numerous, and may extend long distances, often branching as they go.

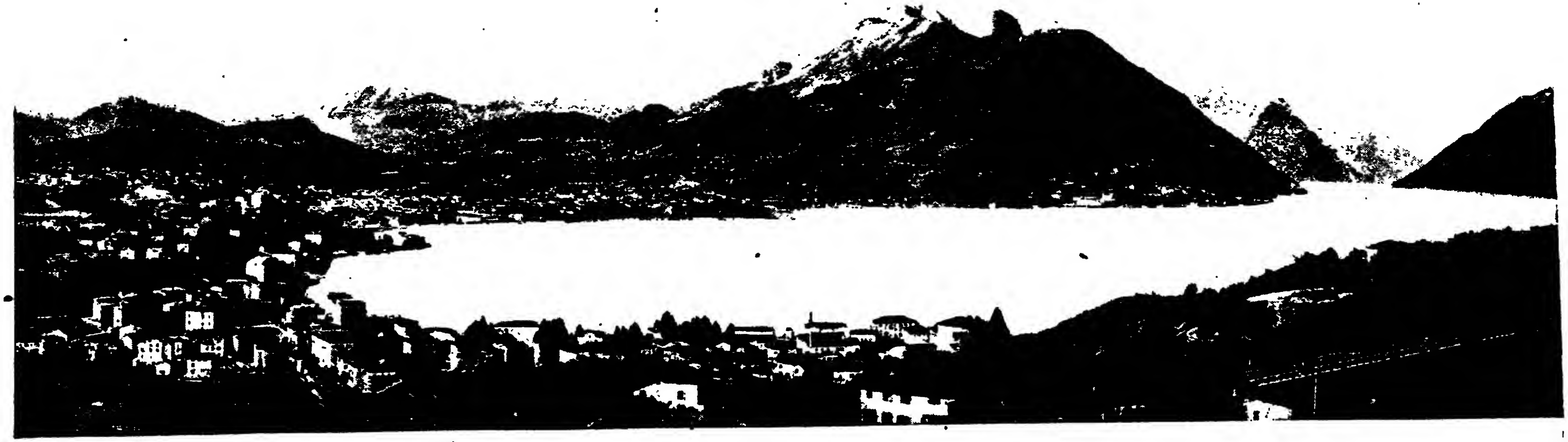
One more outstanding feature remains to be mentioned. It is by far the most mysterious of any in the moon. There are many systems of brilliant rays, which radiate outwards over long distances, from similar bright areas around some of the craters. The most curious quality of these bright rays is that they are unseen until the lunar day is well advanced toward noon—that is to say, until the sunlight strikes them nearly vertically; and then they become extremely brilliant as compared with the general surface of the moon. In the following chapter these and other features of the lunar surface are discussed.



ONE OF THE LARGE LUNAR SEAS—THE MARE SERENITATIS

From a photograph taken at the Yerkes Observatory

LAKES THAT ATTRACT THE PEOPLE OF ALL NATIONS TO ADMIRE THEIR BEAUTY



THE LAKE OF LUGANO AS SEEN FROM ABOVE THE TOWN OF LUGANO; AND THE LAKE OF LUCERNE AS SEEN FROM THE SLOPES OF THE RIGI

INLAND WATER RESERVES

The Past and Present Formation of Lakes and Marshes, and Their Slow Disappearance from the Earth

FEATURES OF THE WORLD'S GREAT LAKES

LAKES are bodies of water collected in basin-like depressions of the land. They are intimately connected with rivers, and not infrequently occur in a chain along a river's course. The beds of the lakes, however, unlike the beds of rivers, are not made by the erosion of running water; the running water finds the beds ready-made, and tends not to deepen them, but to fill them up with silt. If not made by running water, how then are the lake-beds made? Some are craters of old volcanoes; some represent depressions in old boulder-clay deposit, which is always spread very unevenly; some are local subsidences in the land; some have been scooped out by glaciers; some have been caused by barriers across valleys, but most have probably been formed by land movements resulting in the bending up and down of valleys.

It will be noticed, therefore, that though running water does not actually make lake-beds, yet in the majority of cases, by the forming of valleys, it prepares the way for the making of lakes, much as it prepared the way for the making of the fiords on the west coasts of Norway and Scotland. Some geologists have considered glaciers the chief agents concerned in the making of lake-beds, but it is probable that the action of glaciers in this way is very limited. When we examine the beds of most lakes, we find that they show signs of sub-aerial, not of glacial action; and again, when we examine the beds of glaciers, we do not find that they are producing depressions suitable for lakes. Glaciers grind and scratch and polish; they do not gouge and scoop; and though it is quite likely that some small lakes and tarns may have had their beds made for them by glaciers, the beds of such great lakes as Geneva, Albert Nyanza, and Lugano must have been prepared by actual bendings of the earth's crust, or sometimes, perhaps by elevations and great subsidences.

Since earthquakes lower and elevate the land, they often make hollows that become lakes. In 1819, for instance, the Delta of the Indus was shaken by a great earthquake, and the Runn of Cutch, a track of land including 2000 square miles, subsided, and became an inland sea. After earthquakes in the Mississippi valley in the State of Missouri, in 1811–12, about five thousand square miles were lowered and converted into lakes and marshes. After the earthquake in Central Japan in 1891 several lakes appeared.

We have said that barriers across valleys sometimes make part of a valley into a lake-bed. A common cause of such a barrier is a landslip. In 1512 the course of the River Blegno, in Switzerland, was dammed by a landslip and a great lake was formed. The Lakes of Derborence were formed by landslips from the Diablerets. In 1181 a landslip formed a lake 6½ miles long on the plain of Oisans, in the Dauphiny Alps. Villages and forests were submerged, and the inhabitants of the district had to give up farming and take to fishing. After thirty-eight years the lake burst its barrier.

Glaciers sometimes dam river-valleys and form lakes. Thus the ice-dam of the great Aletsch Glacier in Switzerland has formed the Märjelen See. Lakes formed in this way are, of course, far from permanent, and may be suddenly emptied by the bursting of the barrier, or lowered by its gradual melting. In 1818 the Dranse valley was dammed by a glacier and a large lake gathered, but when attempts were made to drain the lake by tunnelling the ice, the ice barrier gave way and fifty people were drowned, and five hundred houses and chalets destroyed. The "parallel roads" of Glen Roy are supposed to represent the

successive levels of a lake which was dammed by a glacier, and which lowered its level as the glacier barrier gave way. In other cases not the glacier itself but its terminal moraine forms the dam which converts part of a valley into a lake.

In a few cases the beds of lakes are made by wind. When the surface of the earth consists of shale and is bare of vegetation, the wind gradually scoops out broad, shallow basins, ready to collect rain in the rainy season. Such lake-beds are found on the great plains of the United States. In sandy deserts subject to sudden changes of heat and cold, the wind has still more excavating power, and there are big tracts of the Sahara which have been worn away to below sea level, and may some day become great inland lakes.

In a few cases, also, lakes are formed by banks and bars of sand, thrown up by the currents of the sea along the coast, which eventually cuts off a lagoon from the sea. Though at first containing salt-water, lagoons may eventually contain fresh. An interesting lake is sometimes formed by a loop of a large river when the river changes its course by short-circuiting across the loop. Such loop-lakes are known as "aigues-mortes," or dead water, and are especially common in the basin of the Amazon.

The table on this page, showing the height, area, and depth of the largest lakes, is given by Dr. H. R. Mills.

The largest lake in the world is the Caspian Sea: the highest known lake is Askal Chin, in Tibet, which is 16,600 feet above sea-level; the lowest is the Dead Sea, which is 1290 feet below sea-level, and the deepest is Lake Baikal, in Russian Asia, which has a maximum depth of 4800 feet.

Many lakes exhibit abrupt transitory changes in level. These changes of level are known as "seiches," and may be either

THE MARJELEN SEE AND THE ALETSCH GLACIER, SWITZERLAND

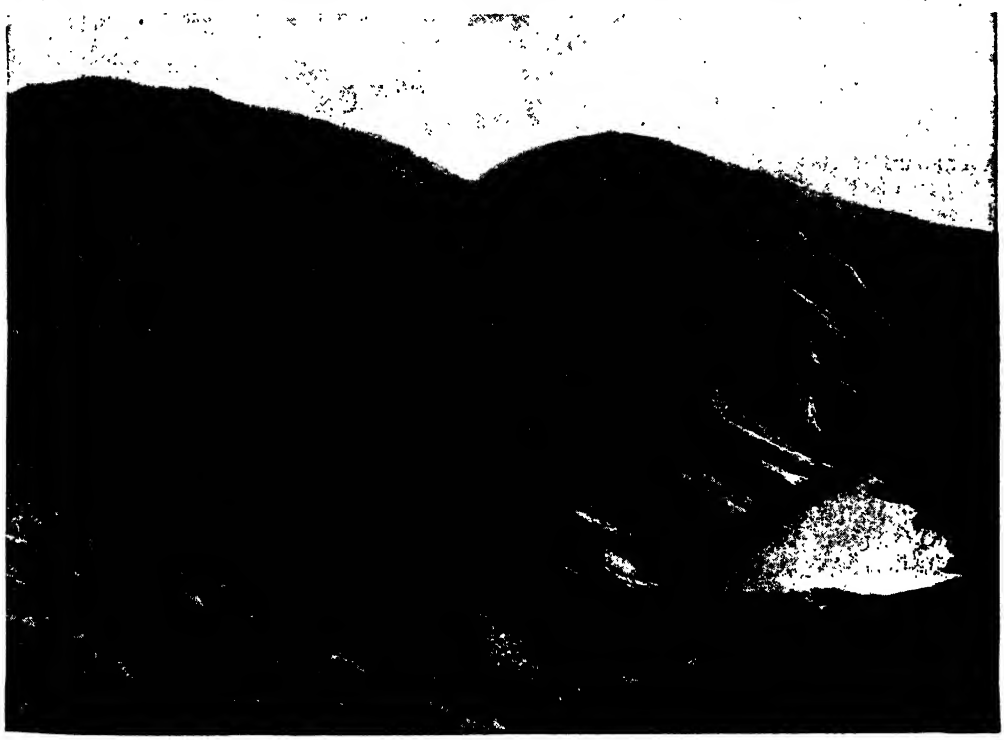
THE HEIGHT, DEPTH, AND SIZE OF THE SIX LARGEST LAKES IN THE WORLD.

Name	Situation	Height Above Sea. Feet	Area in Sq. Miles	Maximum Depth in Fathoms
Caspian	Eurasia	90	170,000	500
Superior	North America	600	31,200	168
Victoria	Africa	3,300	26,900	—
Aral	Asia	150	26,200	37
Huron	North America	580	23,800	117
Michigan	North America	580	22,400	145

local or general. In Lake Geneva the seiches usually affect only a portion of the lake, and have a range of from three to seven feet. The motion is an oscillation, an alternate up and down movement that begins suddenly and lasts for some time. In Lake George, in New South Wales, seiches of the following character have been noticed: "On one occasion, when the lake was very quiet, the water suddenly rose one inch and a half, and fell two inches in three-quarters of an hour; next, it rose two inches, and fell three and a half inches in one hour; finally it rose three and three-quarter inches in forty minutes, and so started a series of pulsations which settled down to two-hour intervals and lasted twenty hours." In the Swiss lakes seiches seem more common by night than by day, and in spring and summer than in winter, and they frequently occur when the sun "suddenly begins to shine from amid heavy clouds." In Lake George, on the other hand, seiches are frequently associated with thunderstorms.

The cause of seiches is unknown. Some have attributed them to underground movements, but they are more probably due to alterations in atmospheric pressure; for similar seiches occur in the Baltic, which have been shown to be connected with the height of the barometric columns.

The temperature of lakes has been carefully investigated, and it has been found that a lake of any depth situated in a temperate country has a mass of cold water which lies along its bottom, and varies little in temperature from month to month. In Loch Lomond, which is about 600 feet deep, the lowest 100 feet of water has a constant temperature of about 42 deg. Fahrenheit, and at the same depth in Loch Ness, Loch Oich, Loch Morar, Lake Geneva, Lago Maggiore, Lago Lugano, and many other lakes the water has about the same heat.



MORAINE-DAMMED LOCH, COIRE DUBH LOCH MHOR, BEN MORE, SUTHERLAND

Lakes perform various geological and climatological functions. Like the ocean, they tend to equalise the temperatures of day and night and winter and summer. They filter rivers, precipitating soil and salts; the beautiful blue of so many lakes is a proof of their efficiency as filters. They furnish an abode for special fauna and flora. But perhaps their most important function is to regulate the supply of river-water to the plains, by serving as reservoirs in time of drought, and by retaining excessive rain in rainy seasons. A vast amount of water can pour into a large lake without much raising

its general surface, and without much increasing its overflow; and likewise a vast amount of water can be drained from a large lake without much much lowering its general surface or diminishing its outflow.

If a river one-tenth of a mile wide flows into a lake one hundred square miles in area, and then continues its course for ten miles to the sea, a rainfall sufficient to raise the level of its last ten miles by twenty-five feet will be intercepted by the lake, and raise the lake's surface only three inches—a rise that will obviously hardly increase its outflow. Réclus shows this regulating action in the case of Lake Geneva: "The gauges used at Geneva establish the fact that the discharge of the Rhône as it issues from the lake is, at its maximum, 753 cubic yards. Now, as the various affluents of the lake supply more than 1400 cubic yards during their highest floods, it is evident that the Lake of Geneva acts as a complete regulator. It keeps back at least one half of the inundation water, which it subsequently empties down gradually when its tributaries have retired to their usual level. It is certain that, owing to the regulating action exercised over the discharge of the river, the plains on the bank of the middle course of the Rhône, from Geneva to Lyons, are comparatively protected against floods."

From what we have said of the manner of the making of lakes, it is plain that they belong to comparatively recent geological periods, and it is also plain that they have no elements of permanence. The river does not deepen the lake; it fills it up, and in time abolishes the lake altogether; the lake dammed by the glacier will last only as long as the glacier lasts; the lake scooped out of the sand by the wind will very probably be choked; the aigues-mortes will soon become a marsh.

THE PARALLEL ROADS OF GLEN ROY

Lakes may contain either salt or fresh water. Some of the salt lakes, such as the Caspian Sea, originally obtained their salt water from the sea, but others, such as the Dead Sea, have collected the salt for themselves from the land. As a rule, lakes with an outlet contain fresh water; without an outlet, salt; but there are exceptions to this rule.

The largest fresh-water lake in the world is Lake Superior, in North America, which is situated 600 feet above sea-level, and covers an area of 31,200 square miles. Lake Victoria Nyanza, in Africa, comes second, covering an area of 26,900 square miles; and Lake Aral, in Asia, is a good third, with an area only slightly less. Then come Lake Huron and Lake Michigan, respectively 23,800 and 22,400 square miles in area. The five great North American lakes, Superior, Michigan, Huron, Erie, and Ontario, together cover an area of 94,650 square miles—an area, that is to say, about the same size as England. Big as these North American lakes are, there is geological evidence which indicates that a still bigger lake formerly existed—a lake 700 miles long from north to south, and covering an area of about 110,000 square miles. All that is left now of this tremendous lake is a few sheets of water scattered here and there, but there can be no doubt of its former existence, and it has been named by geologists "Lake Agassiz." At one time, too, both Lake Superior and Lake Huron were larger and deeper than they now are, as is shown by the series of raised shingle beaches that form terraces round their shores.

The salt lakes are particularly interesting. As we have said, there are two classes of salt lakes—salt lakes that derive their salt from the sea, and salt lakes that derive their salt from the rivers that drain into

them. Salt lakes of marine origin have been cut off from the parent sea by movements of the earth's crust. They are not very numerous, and they tend to dry up. The largest and most typical of these marine lakes is the Caspian Sea. The Caspian Sea is far the largest lake in the world. It covers an area of 170,000 square miles, and is therefore almost six times as large as Lake Superior, and almost twice as large as the combined area of the five great North American lakes. It is not only large—it is also deep; its maximum depth is 3000 feet, which is more than three times the depth of Lake Superior.

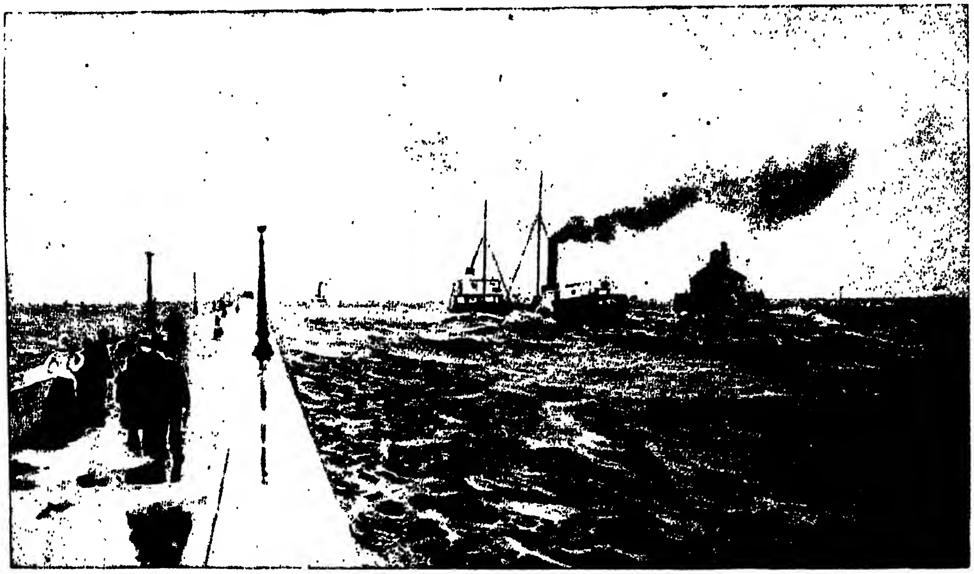
At one time this great lake was certainly continuous with the Black Sea, for between the two is a chain of salt lakes and marshes. Also, the shells in the Caspian Sea are the same as the shells in the Black Sea, and banks of similar shells stretch between the two seas. It seems probable, too, that at one time a great arm of the Caspian Sea stretched northward over the steppes of south-eastern Russia, even as far as the Arctic Sea, since in that direction there are still salty plains and little salt lakes, and since seals which seem a variety of the Arctic species are found in the Caspian Sea. It is strange to think that a lake so far to the south should have seal fisheries, yet the seal fisheries of the Caspian Sea are a big and flourishing industry.

At present the surface of the Caspian is about 90 feet below sea-level, the fall being due partly to the movements of the earth's crust and partly to evaporation. At present it seems that the influx of water to the lake about balances evaporation, but the surface of the Sea of Aral, which once joined the Caspian, is slowly sinking year by year. Were the Caspian to fill up again to sea-level it would flood several hundred thousand square miles of the steppes. Since the rivers constantly add salt to the Caspian, and since evaporation prevents any increase of water, one would expect the Caspian to be excessively salt, and it is rather surprising to find that on the average it is not so salt as the general ocean, and not even so salt as the Mediterranean. How is this? The reason of this apparent anomaly is that "the shelving shores, and particularly the wide, shallow inlet of Kara-Baghas, act as natural salt-pans, evaporating the thin layer of water covering them and causing a deposit of crystalline salt, which is thus being gradually withdrawn from solution, while evaporation is made good by a continual supply of fresh water."

LOCH LOMOND AND THE ISLANDS THAT LIE WITHIN IT

In the Kara-Baghas itself, which is an offshoot of the Caspian Sea, the waters are much salter, and it has been estimated that every day 350,000 tons of salt are swept into it through the shallow inlet. So salt has the Kara-Baghas become that the seals have left it, and no vegetation will grow on its banks. Still salter is the arm of the sea called Karasu, where the

salinity rises to 5·7 per cent. All round the Caspian Sea there are shallow salt pools and lagoons where salt is concentrated and deposited. "One basin," says Réclus, "still occasionally receives water from the sea, and has deposited on its banks only a very thin layer of salt. A second, likewise full of water, has its bottom hidden by a thick crust of rose-coloured crystals like a pavement of marble. A third exhibits a compactness of salt, in which glitter here and there pools of water situated more than a yard below the level of the sea. Lastly, another has lost by means of evaporation all the water which once filled it, and the strata of salt which carpets its bed are partly covered by sand."



LAKE SUPERIOR, THE LARGEST EXPANSE OF FRESH WATER IN THE WORLD

Though a lilliput compared with the Caspian, the Dead Sea is a yet more famous lake, famous both because of its salinity and because of the depth of its surface below sea-level. It lies no less than 1290 feet below the level of the Mediterranean, and is fed by the Jordan, which enters at its north end and finds no exit. The sea now covers an area of only 460 square miles, but there are layers of marl and beds of salt on the slopes surrounding it, and it is probable that at one time it stretched from the foot of Lebanon to the north of the Red Sea. The lake well deserves the adjective "dead," for no fish live in its waters, and no vegetation grows on its banks. Its salinity is much greater than the salinity of the Caspian Sea, and eight or nine times as great as the salinity of the sea, and its salt contents differ greatly from the salt contents of the sea. It contains about 26 per cent. of salts, but the predominant salt is not chloride of sodium, or common salt, as in the case of the Caspian Sea, but chloride of magnesium. It has 15·9 per cent. of chloride of magnesium, and only 3·6 per cent. of sodium chloride. It is probably the large percentage of magnesium chloride that renders the water so destructive to life. Though the Dead Sea must at one time have approached the Red Sea, it is unlikely that it communicated with it, since no trace of iodine is found in Red Sea water, and the foraminifera in the mud of the Dead Sea do not belong to Red Sea species. Fragments of bitumen are found floating on the surface of the Red Sea; hence it is sometimes called Lake Asphaltides.

To the west of the Caspian lies Lake Elton, a very saline lake, whose bed consists of layers of salt constantly thickening from year to year. In summer, when evaporation is rapid and the lake diminishes in size, its shores look like immense snowfields; and though every year some millions of salt are extracted from the lake, its salinity does not seem to decrease.

In America, in the State of Utah, we have the remarkable Great Salt Lake, which is a shallow sheet of water averaging about 6 feet deep and 248 miles in circumference. It contains about three times

as much common salt as the sea, and has also a considerable percentage of sulphate of potassium and sulphate of magnesium. So saline is the water that it is difficult to swim, because the legs will not sink in the water, and it is said that one might float on the top of the water and fall asleep without incurring any danger of drowning. But the salt water is so acrid that if it enter the eye it causes great pain, and inhalation of the spray causes a spasm of coughing.

The only living things in the lake are small worms that burrow in the sand of the shore, and a seaweed of the Nostoc species, and on the shores of the lake only such shrubs are found as can tolerate a saline soil. Nevertheless, swans, ducks, gulls, and wild geese float on the pond, and the banks are peopled with a multitude of pelicans.

At present rainfall and evaporation about balance each other, and the lake preserves a more or less constant level, and neither increases nor diminishes, but, like most other salt lakes, it has known better days. It is, indeed, merely a remnant of a greater lake which formerly was about 200 miles long, and covered an area of 19,750 square miles, and which has left terraces on the slopes and mountains as records of its former extent. This great original lake was a fresh water lake, and drained into the Pacific by the Snake and Columbia Rivers. To the west of this great lake there was a second fresh-water lake almost as large, also draining into the Pacific. As meteorological or geological conditions changed, and these lakes dried up, they became more and more saline, and the deserts of the Great Basin are largely due to the precipitation of salts from the retreating lakes.

THE DEAD SEA, WHICH IS GRADUALLY INCREASING IN DEPTH

The table below, collated from tables given by Geikie and Bonney, shows the comparative saltness of various lakes and seas.

THE SALTNESS OF LAKES, EXPRESSED IN PARTS PER THOUSAND

DEPOSIT	English Channel	Caspian at Baku	Elton Lake	Great Salt Lake	Dead Sea
Chloride of Sodium	27·059	8·5207	38·3	118·628	36·372
Chloride of Potassium	·765	Trace	2·3	8·62	8·379
Chloride of Magnesium	3·666	0·3039	197·5	14·908	159·774
Chloride of Lime	—	—	—	—	47·197
Sulphate of Magnesia	2·295	3·2493	53·2	—	—
Sulphate of Lime	1·406	1·0742	—	·858	0·88[illegible]
Sulphate of Soda	—	—	—	9·321	—
Sulphate of Potash	—	—	—	5·363	—
Carbonate of Lime	·033	0·0554	—	—	—
Bromide of Magnesium	·029	—	—	—	8·157

MARSH-LAND DUE TO THE SILTING UP OF A RIVER VALLEY NEAR NEWQUAY

Many rocks have been formed by the precipitation of salts from lake and sea water. The least soluble salts are the first to be precipitated. Evaporation of lake water having a composition resembling sea water would result in a precipitation of gypsum (sulphate of lime), followed by a precipitation of rock salt, and this order is found in saliferous formations. In the case of the Dead Sea, and Lake Elton, and other lakes where the most plentiful salt is the chloride of magnesium, large amounts of chloride of sodium have already been precipitated; and if more chloride of sodium is added to water containing large quantities of chloride of magnesium, the chloride of sodium is precipitated. Hence, when the Jordan brings down additional chloride of sodium to the Dead Sea, the salt is quickly precipitated. The bottom of the Dead Sea, accordingly, consists of common salt and gypsum mixed with mud.

As we have already said, most lakes tend to be filled up. In the course of such filling up they are converted into a marshy condition, and many marshes are simply half-dried lakes. Not infrequently a lake full of water in the rainy season may dry up partially and become a marsh in the dry season. But marshes also originate in other ways. Along the course of rivers subject to overflowing which traverse low-lying land

MARSH-LAND TURNED TO ACCOUNT—TOTTIFORD RESERVOIR, CHRISTOW, DEVON

there are always swamps and marshes; and if the river be large it may form correspondingly large swamps and marshes. Even apart from overflowing rivers, any great stretches of level land become marshes if there be sufficient rainfall. The great plains of Brazil crossed by the Paraguay and its tributaries exhibit a series of immense marshes. Lake Tchad, in Africa, is so surrounded by bogs that its true dimensions cannot be defined. Where the ground is rich in decayed vegetation the marshes are known as peat-mosses, or bogs, and these are specially interesting as the factories where coal is prepared for future generations. One-seventh of the whole area of Ireland is

A MANGROVE SWAMP IN THE MALAY STATES
The photographs on these pages are by the Photochrom Company, N. P. Edwards, W. Lamond Howie, and others.

covered with peat-bogs. The Bog of Allen co ers no less han 238,500 acres, and has an average dep h of 25 feet. Usually peat-bogs bulge up in their centres; and occasionally the oozy mass gives way and a deluge of ooze inundates the surrounding country. More than a century ago Solway Moss burst its bounds, and buried a number of cottages up to their roofs, and covered four hundred acres of farm-land. In some places the overflowing boggy matter was fif een feet deep; and when the overflow ceased, the level of the bog was found to have fallen twenty-five feet. In 1883 even greater devastation was wrought by the bursting of some bogs in the neighbourhood of Castlerea. Thousands of acres of land were submerged, and roads were covered in places to the depth of twenty-six feet.

Peat is an excellent preservative; and the remains of many extinct animals, such as bears and elks, are found in British peat-mosses. Many bogs are the consequences of the destruction of forests, and many of the peat-mosses in England and Scotland were made by Roman axes. In Canada and Newfoundland there are enormous stretches of peat bogs, and along the frontiers of North Carolina and Virginia extends the great peat-bog the "Dismal Swamp."

Some of the greatest marshes of the world are the salt-water marshes on the shores of the sea. Along the coast of Florida a belt of marsh five to twenty miles wide stretches for many miles. These marshes are often known as mangrove swamps, because they are covered with thick jungles of mangrove trees, which have bird-nests on their branches and crabs and barnacles among their roots. Along the shores of the Gulf of Mexico there are millions of acres of marshes covered not with mangroves but with cypresses, and these, again, are known as "cypress swamps." For centuries it was believed that swamps and marshes gave off poisonous vapours that caused malaria, but it is now known that the malaria is not due to poisonous vapours, but to mosquitoes.

PLANTS CAUGHT IN THE ACT OF CHANGE

ŒNOTHERA LAMARCKIANA

ŒNOTHERA GIGAS

ŒNOTHERA ALBIDA

ŒNOTHERA OBLONGA

ŒNOTHERA SCINTILLANS

How new species come into being is one of the most important problems in Biology. Professor Hugo de Vries happened to catch the evening primrose, Œnothera lamarckiana, when it was mutating, and on this page are pictured with it four of the fifteen new species which he grew from it. Of these fifteen, Œ. gigas was the strongest and finest, and only appeared three times. Œ. albida was noteworthy because, at a very early stage of the seedling, its novelty was apparent; it was a small and pale species. Œ. oblonga had narrow leaves with long stalks. Œ. scintillans was the rarest form of the cultures, and proved an inconstant species, tending to give rise to other species. These pictures are reproduced by permission from the plates in "The Mutation Theory," by Prof. Hugo de Vries.

THE BIG STEPS OF CHANGE

How Two Botanists—a Dutchman and a Dane--Have Added to our Knowledge of Life's Broadening Growths

AN AMSTERDAM THEORY OF MUTATIONS

THE science of heredity is still young, and, as is usual with young sciences, still requires to be discussed along various lines, each associated with the name of some special student and pioneer. Gradually we are learning, and shall learn, how these various views and methods are to be employed for a completer science, which can proceed confidently from first principles to details. In our present attempt to make a fresh review and judgment of the most rapidly changing and developing part of all science—always excepting radio-activity—we have now successively dealt, in logical order, though, for a curious reason, not in chronological order, with the work of Galton, Weismann, and Mendel. We now come to the name and the work of the most conspicuous living student of heredity on the new lines, with the exception of the great English Mendelian to whom we must proceed next. The student to whom we refer is the famous Dutch botanist Professor Hugo de Vries, of Amsterdam, whose great book, "The Mutations Theory," was published in the first year of the present century, the year after the sensational rediscovery of Mendel's forgotten work of a generation before. The book is large, difficult, complicated, and only very lately has it begun to be accessible to the English reader, but it has played a leading part in the development of our knowledge during the last decade, and there is little doubt that the friendly rivalry and co-operation of the Mutationists and the Mendelians, to use the names now in general vogue, is the the chief hope of the science of genetics for many years to come.

Two years after the publication of "Die Mutationstheorie" there appeared a very important paper by another Continental botanist, Professor Johannsen, of Copenhagen, which modified, confirmed, and extended the work of De Vries. Any serious and stable study of heredity today demands acquaintance with the experiments and discoveries of these two distinguished botanists, the Dutchman and the Dane; and we have only to define the "mutations theory" in order to see that, if it be well founded, it marks a conception of heredity, and therefore of evolution, fundamentally distinct from that which is set forth in "orthodox Darwinism"—as we now find ourselves saying.

De Vries introduced the term mutation to express his conception of the origin of species, or of a new specific character, when this occurs by the taking of a single new step. He believes that these new steps, which may be of very great size, are by no means very common or general, and that *in them alone is the true origin of species.*

At once we see that this is a theory which is directly and notably opposed to Darwin's. (Readers of POPULAR SCIENCE will not fall into the stupid and tiresome error of supposing that the doctrine of organic evolution is in question when we argue its *how*, any more than the doctrine of gravitation is in question though its *how* is still utterly mysterious.) Darwin's theory was that organic evolution was by the natural selection of minute variations, which were incessantly occurring in all directions, from generation to generation of all living creatures. Darwin could have made a better case for organic evolution, apart from any special theory, if he had laid some stress upon the appearance of large, striking variations, of the kind which are called in ordinary language "sports," and to which De Vries has given the scientific name of "mutations." But it was not Darwin's way to use evidence for his case which he did not himself believe in; he was a truth-seeker, not a party politician or an

advocate. It seemed to him that "sports," though they looked at first like the obvious origin of new species, did not withstand close inspection; they were, above all, inadequate to account for the adaptation of species to their environment, and there were many other criticisms of their apparent claim to furnish the origin of species, according to the knowledge available to Darwin.

The Confirmation by De Vries of Huxley's Belief that Nature Sometimes Makes Jumps

Professor Huxley, Darwin's great champion, was wise in his generation in this respect, as the following very interesting passage shows: "Mr. Darwin's position might, we think, have been even stronger than it is if he had not embarrassed himself with the aphorism 'Natura non facit saltum,' which turns up so often in his pages. We believe . . . that Nature does make jumps now and then, and a recognition of the fact is of no small importance in disposing of many minor objections to the doctrine of transmutation." The argument of De Vries and his school today is that Huxley here was right, and would have been still more right had his criticism been far stronger. Nature does sometimes make leaps, or "saltations," as they are sometimes called, and these leaps or jumps (cf. the word salient, from the same Latin root, to describe what jumps or dances above its fellows) are none other than the "mutations" of De Vries, in which, as against the minute variations accredited by Darwin, he and his school believe the origin of species to occur.

As we have already briefly seen, the work of De Vries and the modern experimental school in general has shown us that there was a most fundamental error at the root of the Darwinian theory of organic evolution. Darwin assumed that the minute random variations he discussed were inheritable. Today we are taught, by work done since Darwin's death, that the differences which occur between offspring and parents are of several different kinds, having different consequences, and must be distinguished accordingly.

The Mutation Theory of De Vries' Forecast in the Seventeenth Century

It is, above all, to De Vries that we owe the new view that the "sports" rejected by Darwin and the early builders may be something like the headstone of the corner. Not that this new view is an exception—though there are exceptions, or there would be no evolution — to Solomon's dictum about new things in general. In point of fact, the theory of evolution arising in sports or mutations is fairly definitely hinted at in Aristotle; and Professor Punnett has noted a passage in the writings of Sir Thomas Browne, the famous author of the "Religio Medici," in which that remarkable man definitely states the mutations theory in all essentials to explain the various colourings of men and foxes, lions, crows, etc., and actually concludes: "All which mutations, however they began, depend upon durable foundations, and such as may continue for ever."

That is the modern "mutations theory" of De Vries in one powerful sentence, published in the year 1650—the theory that the characteristics of species arise in mutations, which "depend upon durable foundations," *in the germ-cells,* "and such as may continue for ever," because of the nature of the germ-plasm, its "continuity," and "immortality," as Weismann has since taught us to say. And with that remarkable definition and anticipation of Sir Thomas Browne is involved the discarding, as aids to evolution, of all variations which *do not depend* upon durable foundations, because they are not built upon the germ-plasm, are not rooted in that, but are merely the accidental results of the interplay between the individual body and its environment.

The Difference Between Mutation and Fluctuation a Vital Point

Some years before De Vries published his book, our own great student Professor Bateson, in his "Materials for the Study of Variation," had shown that there exists a profound and all-important difference between those variations which do not depend upon the durable foundations of the germ-cells and those which do. Today, we are compelled, above all by the special studies of De Vries and of Johannsen, soon to be described, to acknowledge that distinction. And we must speak, in the language of De Vries, of the merely nutritive or environmentally produced difference as a fluctuation, and of the germinal difference as a mutation. And here we must beware of a very common error, not inexcusable, into which many have fallen.

The difference between a mutation and a fluctuation is one of nature, not of size. The point is not, as so many have supposed, that whereas a fluctuation is a minute and scarcely measurable variation from the type of the species, a mutation is something large, extraordinary, obvious. A fluctuation may be very large and obvious, and a

mutation may be very minute and subtle. If we consider cases of morbid nutrition, including, for instance, such a disease as rickets, we see that a mere fluctuation, according to the biological definition, may yet show itself in such a striking form as aggravated knock-knees. No mutation of the bony characters of the human body would be likely to approach in intensity such an abnormal condition of the bones of the leg. But that condition is nutritive, not founded upon the sure ground of the germ-cells, and it is to be ignored from the standpoint of heredity, as any attempt to breed a knock-kneed species from such parents would certainly show.

How the Experiments of De Vries Showed the Limits of Selection

On the other hand, a true mutation is by no means necessarily anything so notable and largely novel as, for instance, the sudden appearance of a nectarine upon a peach-tree. On the contrary, even the tiny but definite differences which modern Mendelism studies, and many of which are quite as minute as mere "fluctuations," may yet, if only they be dependent upon differences in the composition of the germ-cells, furnish the origin of new forms that will persist.

Having these principles and definitions clearly in mind, we may proceed to the precise contributions of De Vries to our subject. In the first place, he carried out a number of experiments in which he tried to modify the characters of certain plants by means of simple, straightforward selection along Darwinian lines. He found that selection made a difference at first, but that thereafter, no matter how stringently and accurately he selected for certain characters, nor how many generations he practised upon in succession, all that he could do was to maintain the characters obtained very early in his experiment. Here, indeed, begins the crucial experimentation which shows how sharply set are the limits of selection.

The Illustration of the Shirley Poppies—a New Type Suddenly Evolved

The argument of De Vries and the Mutationists therefore is that there must be something else, other than ordinary fluctuation, which is really effective in changing species. This something else is the process he calls mutation, and the products of it may be called mutants—the changing things. Let us see what actually may happen—and let us hope some day to discover how and why it happens.

The Shirley poppies are a celebrated illustration, which may be cited in the words of Mr. R. H. Lock, a prominent botanical student of heredity. He writes as follows: "Of the origin of a new type of plant in this definite and sudden fashion, the Shirley poppies furnish an excellent example. These originated in a mutation of the common wild field poppy. In 1880 the Rev. W. Wilks, Vicar of Shirley, near Croydon, noticed among a patch of this plant growing in a waste corner of his garden a solitary flower, the petals of which showed a very narrow border of white. The seeds which this flower produced were sown, and next year, out of about two hundred plants, there were four or five upon which all the flowers showed the same modification. From these, by further horticultural processes, the strain of Shirley poppies originated. We may point out in passing that if the original plant had been self-pollinated, a much larger proportion of the new type might have been expected to appear in the next generation."

The Theory that New Breeds Arise from Definite Novelties

For De Vries and the modern school of biologists, such an instance of what actually happens is invaluable and all-significant. In his judgment all new domestic breeds have arisen by the "discontinuous" method as definite novelties; and this which we know, and which Darwin, of course, well knew, to be so generally the case for the origin of new domesticated forms of animals and plants, is in the belief of the mutationist school true also of the origin of natural species as well. There is the essential difference between the Darwinian and the mutationist theory. And since the latter lays so little stress as to be no stress worth mentioning upon the process of selection, which was essential in Darwin's theory, we now often speak of the opposing camps as respectively selectionist and mutationist. For, as Mr. Lock puts it: "If new types are not produced among domesticated productions by the action of artificial selection, and all that selection can effect is to pick out definite novelties when they occur, the analogy between natural selection and artificial selection breaks down, and a large and important section of the evidence in favour of the production of natural species by the action of natural selection is destroyed. In the place of this explanation De Vries would put the theory of mutation, according to which new species arise by single steps

as definite novelties, just in the same way as we find that domestic varieties are produced. More than this, De Vries believes that he has discovered a set of new species in the very act of originating from an old one in this way, a discovery which affords the basis and groundwork of the views which he puts forward."

The Timely Illustration Found by De Vries in the Evening Primrose

And so we come to this celebrated observation of De Vries upon the species of evening primrose, a native of America, which is known as *Œnothera lamarckiana*. There is something right and apt in the name of this species, carrying us back to the great pioneer of evolution who declared that altered external conditions may sometimes originate real transmissible changes in the germinal characters of living things. Certain specimens of this plant escaped from a garden in Holland, and De Vries found among the "escapes," or their offspring, two distinct new forms, each unlike all the rest. Each occurred in a separate patch, as if a single plant had borne all the new individuals in each case.

De Vries made full use of his remarkable opportunity, and the first fact which he discovered was that the seeds of these plants, when sown in his garden, produced offspring like the parents. In a word, two new species had actually been observed and proved to arise from an old one in a state of nature. Following on this, De Vries set to work to study more closely the cultivated offspring in his garden of the various types of evening primroses which were first observed running wild as garden escapes, and after very wide and detailed experiment he showed that out of fifty thousand individuals grown so that they could be defined and identified, more than eight hundred, or about one and a half per cent., were novel, differed from *Œnothera lamarckiana*, and could only be called mutations.

The Theory that a Period of Mutation Occurs Once in Four Thousand Years

It looks as if De Vries had had the great good fortune to chance upon a species just when it was breaking up into a number of new species. Until this famous research of his it had never been supposed possible to make observations directly upon the origin of new species *under natural conditions*. But De Vries showed that it was possible to do so; and the results which he obtained were, as we have seen, of a most remarkable and unexpected kind. Perhaps the actual work of De Vries in his experiments was better than his interpretation of it. We need not here trouble ourselves at length with his various theories as to the causes which lead species to break up, nor as to the correspondence between the known characters of species and certain assertions of the geologists. De Vries is as prolific a speculator as an experimenter. He supposes that something like four thousand unit characters, each of which has arisen by a single mutation in the past, would account for the constitution of the highest form of life we know—ourselves. He also supposes that a period of mutation recurs about once in every four thousand years, and by multiplying four thousand by itself he concludes that a period of sixteen million years would suffice for the gradual unfolding of the body of man from the lowest forms of life at a rate of one mutation every four thousand years. All this is, to say the least of it, highly fantastic, but it may be recorded briefly for its curiously significant contrast with the solid qualities of the Dutch botanist's work, so long as he confined himself strictly to observation.

A Vindication from America of Some of De Vries's Contentions

Whatever may be said of his speculations, the facts which De Vries described were in themselves startling enough, and botanists could not accept them, it need hardly be said, without confirmation. That was ere long afforded by the experimental school of American botanists, who have such splendid opportunities provided for them by the wealthy men of their country—above all, by Mr. Carnegie's foundation. At the New York Botanic Garden, Professor Macdougal was able to show that what De Vries observed in the case of the seeds of the *Œnothera lamarckiana*, as found in Holland, was undoubtedly as the Dutchman described it. Indeed, Macdougal, somewhat improving upon De Vries's methods, found mutation to be occurring in about three per cent., rather than one and a half per cent., of the total number of seedlings grown from seeds sent across to him from Holland. And close observation, in the hope of finding other species which were undergoing mutation, in the fashion of *Œnothera lamarckiana*, was rewarded in some instances.

Mutation must therefore be accepted as a fact, and the question of its interpretation becomes a pressing one, especially since so much has been claimed for it by De Vries himself. He naturally set to work to see whether similar phenomena to those of his evening primrose could be observed in the

case of other species available to him. He grew and examined large numbers of the seedlings of a great proportion of the plants in his district, but found no sign of mutation in any of them. Hence he concluded that species have long lives of stability, rarely but notably chequered for relatively short periods by a sudden and sharply contrasted tendency to mutation, and he argued that the evening primrose he studied first happened to be in one of these rarely recurring stages of mutation, while the other species were not. As we have seen, he even ventured to name periods of years to correspond to the rhythm he imagined between stability and mutability.

The Want of Evidence of Any Rhythm Between Stability and Mutability

No real evidence of any kind exists in favour of this view. Mutation has its causes, of course, and when those causes are at work mutation is the result. In their absence a species remains stable. And we shall later see that Professor Macdougal and others are beginning to show how the application of certain factors from without may at any time start mutation, or something very like it, in a number of species already experimented upon.

Having said so much of the "mutations theory" of De Vries, the Dutchman, as published in 1901, we must now proceed to look at the remarkable work done by Professor Johannsen, the Dane, and published in 1903. That work has since been confirmed in other quarters, and is now part of the acknowledged achievements of biology in our century. In the title of his paper Johannsen introduced the term "pure line." He studied plants which could fertilise themselves, and he gave the name of "pure line" to all the individuals thus descended from a single individual.

Johannsen's Novel Achievements and Proof of the Theory of Pure Lines

His first experiments were carried out with barley and kidney beans, and the case of the beans will serve our present purpose. Johannsen studied the weight of the beans, and made a remarkable discovery. When he weighed a number of beans that were simply a random sample, he found that they had a mean or average weight around which they varied. The curve of such "continuous variability" can be plotted on a diagram, and is the basis for the mathematical study of variation.

But living creatures cannot thus be reduced to paper; they must be studied at first hand. Johannsen's random sample of beans was really a "population" consisting of the offspring of nineteen parents; and when this population was analysed separately, Johannsen found that the nineteen pure lines of which it was composed were all distinct. Each of these pure lines had its own characteristic average size of seed and characteristic degree of variation around the average.

If, now, we select persistently the biggest of the seeds, or the smallest of the seeds, *within any one pure line*, expecting steadily to increase or decrease the size of the seeds in successive generations in consequence, we find that nothing of the sort happens. The differences in the weight or dimensions of the seeds, within any given pure line, are not inherited; the offspring of the lightest seeds, within the pure line, are as heavy as the offspring of the heaviest. And, further, the reasonable but paradoxical result is obtained that the offspring of small seeds will be heavier than those of larger ones, if the small seeds are small specimens of a pure line whose average weight is high, while the large seeds are merely large specimens of a pure line whose average weight is lower.

Johannsen's Contention that there is no Variation in Pure Lines

Now let us consider what selection, "artificial" or "natural," would accomplish in such cases as this. Plainly, we may practise as rigorous selection as we please, within a pure line, and the result will be exactly *nil*. All the individuals, in such a line, are fundamentally, germinally identical. The differences between them are nutritive, accidental, secondary—personal, not racial. It follows that we shall get seeds of the same average weight, no matter whether we breed from the largest or the smallest specimens, within that pure line. In such conditions selection is impotent.

Suppose, now, that we practised our selection upon a "population," in Johannsen's sense, which was really a mixture of pure lines. The result would simply be that, if we were selecting for heavy beans, we should ultimately isolate the pure line which was characterised by the highest average weight of bean among its members. After that we might continue our selection for as many generations as we pleased, but the weight of our beans would remain constant, because we were merely selecting within a pure line, and the selection of the heaviest beans within that line would produce no heavier offspring than the selection of the lightest. Something more than selection,

something constructive, creative, would be required for any further advance. This is the something that Darwin forgot.

The theory of the pure line applies, as has been now proved, to many characteristics besides size or weight of beans. But obviously its significance and working out must become very complicated directly we study a population of living creatures where self-fertilisation does not occur. For then the pure lines will very frequently be crossed and confounded by the process of bisexual reproduction, and the tracing of them would soon be impossible. But though we may be unable to trace them, yet, if they really exist, we shall see at once how inadequate is the Darwinian assumption that the selection of variations will produce indefinitely extensive results in the case of any living species. In the particular case just cited, we see how limited is the power of selection, and how the personally small individuals of a large race will have large offspring, and the personally large individuals of a small race will have small offspring; so that natural selection or artificial selection, steadily choosing individuals without discriminating between those characteristics which are accidental and personal to them and those which are in their race, though perhaps not displayed at all in their persons, would find itself constantly fooled.

The Relation Between Bateson's Work and that of De Vries and Johannsen

Briefly, then, the Dutchman and the Dane, from Amsterdam and Copenhagen, unite to assure us, as the result of their studies in the field of botany, that the distinction between "mutations" and mere "fluctuations" is all-important. Not that the distinction had been entirely ignored in this country. On the contrary, it must be stated, in justice, that Professor Bateson, whose name we specially associate with the establishment and development of Mendelism in our century, had long studied this subject before the nineteenth century closed, and had sought to distinguish between two kinds of variation, which he called respectively "continuous" and "discontinuous." He applied the term continuous variation to the fine gradations observed in the weight of beans, or the height of men, or what you will, when large numbers of them are examined statistically. This, we now know, is the kind of variation which has been studied by the biometricians for its bearing upon heredity, and which has no bearing upon heredity. Bateson further insisted upon the existence of discontinuous variations, which arose as definite, unmistakably different characters, not just fluctuating on one side or another and a mean, like the marks on a target. These were marks *of a different kind*. It is now, of course, obvious that the "continuous variations" of Bateson are the "fluctuations" of De Vries, and that "discontinuous variations" are the "mutations" of the Dutch botanist's terminology.

The Gist of Johannsen's Observations that Mutations and Fluctuations Differ

Strong suspicions at once arise that these two phenomena are different not merely, or even necessarily, in measure or quantity, but in kind; that, in the extraordinarily exact words in which Sir Thomas Browne anticipated our new theory by two and a half centuries, "Mutations, however they began, depend upon durable foundations, and such as continue for ever," whereas fluctuations or continuous variations, mere oscillations around the mean of their type or line, have no durable foundations in the germ-cells, are therefore not inherited, and are therefore worthless as foundations for any theory of evolution. But it was upon these that Darwinism was founded.

And, lastly, as we have seen, the work of Johannsen upon "pure lines" has begun to provide us with a most elegant and instructive criterion of this difference, now seen to be all-important, between the variations that matter and the variations that do not. The question is still the subject of necessary experimentation, and will long be so, but Johannsen has definitely taught us that, for certain characters of certain plants, at any rate, the difference between fluctuations and mutations, between continuous variation and discontinuous variation, between mere oscillations and the real and vital "jumps," which Darwin rejected, is real and cardinal *when tested by selection*.

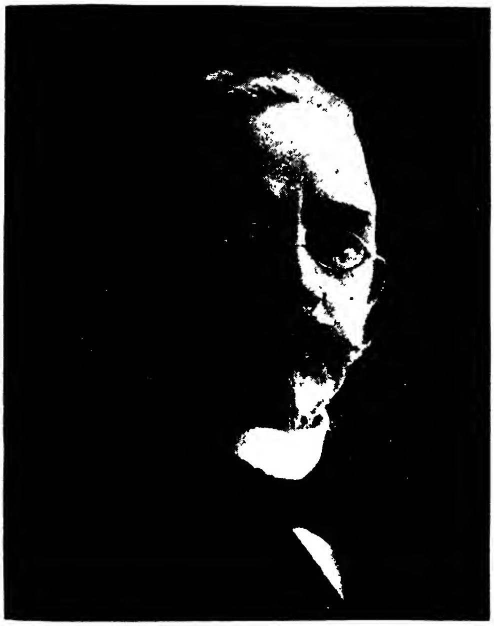
The Relation Between the Theory of Jumps and Natural Selection

For experiment shows that selection of mutations alters a race, so long as further *mutational* material for selection remains, but that selection of mere fluctuations effects nothing. How Darwin would have loved to learn the manner and degree in which his own knowledge has been superseded! And how the Darwinians are distressed!

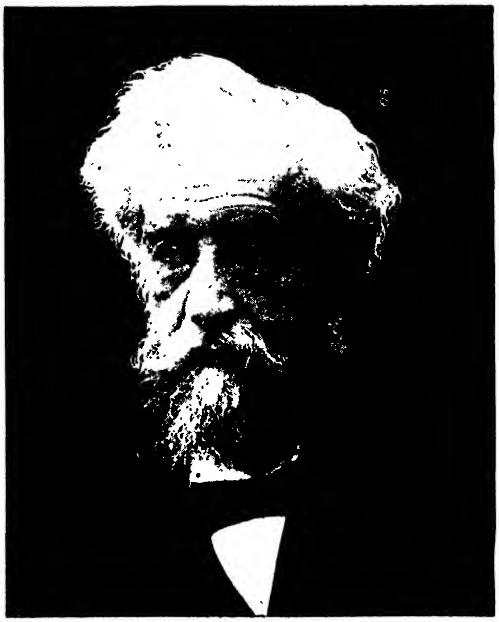
Yet let us beware of rashly supposing that "natural selection" may henceforth be ignored. Certainly none of the leaders of the new developments could be quoted

as of that opinion, and several of them have definitely spoken far otherwise. If conditions are suitable—that is to say, if there be over-production and a struggle for life—natural selection must obtain, and the best adapted must survive. Only we now realise, more clearly than ever before, that they may owe their survival to characters which are germinal and racial, or to characters which are merely personal to themselves. That matters nothing to them, but it matters everything for the consequences of the selective process. For if selection selects mutations, the race will change accordingly; if it merely selects fluctuations, the race will not be affected at all—as in the crucial was seeking to solve, simply by choosing, in each generation in turn, those candidates whose personal adaptation happens to be most complete. Their advantages may rank merely as fluctuations, may therefore be non-transmissible, and matter nothing for evolution, but they nevertheless serve in some degree to explain the adaptation existing in the world of life at any given moment—in any given generation.

The origin of mutations or discontinuous variations all this while remains the problem of problems. We have already seen cause to believe that the reason why this problem always eludes scientific search lies in the very nature of life. Such, at any rate, is



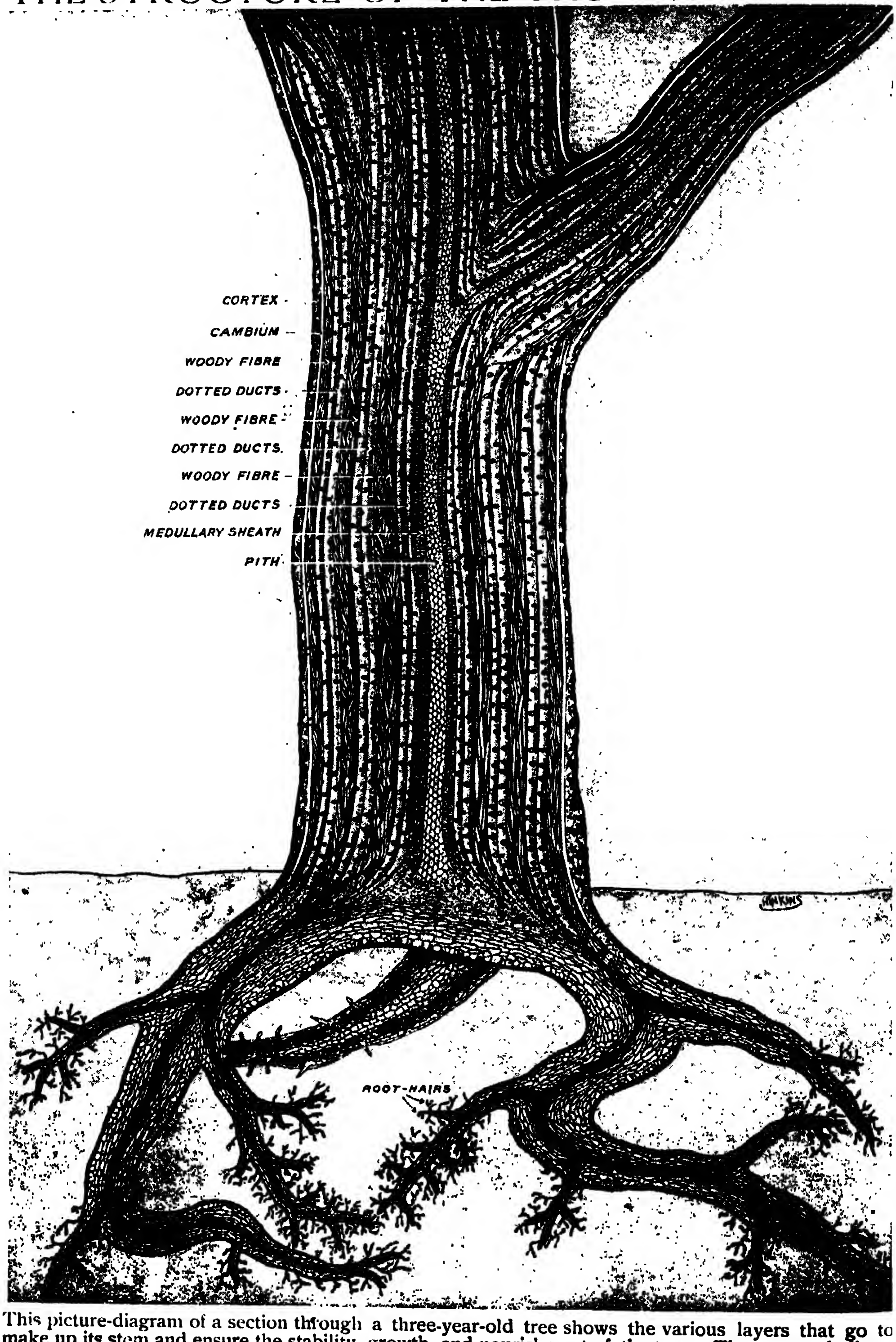
PROFESSOR WILHELM JOHANNSEN



PROFESSOR HUGO DE VRIES

experiments of Johannsen. Now, there is every reason to suppose that, in the overwhelming majority of cases, the differences upon which natural selection has any opportunity to act are mere fluctuations, and that mutations, which alone matter for evolution and the origin of species, are relatively very rare. By so much is the potency of natural selection *for the future* reduced, though it retains its power to determine who shall be the survivors and who the rejected in any given generation. That may be a relatively humble function for natural selection to discharge, but it is by no means to be neglected. For, even so, natural selection contributes substantially to the problem of adaptation, which Darwin the answer cogently returned to it by Bergson. But that answer does not mean, either for Bergson himself or for any real thinker, that we may now save ourselves further trouble and make no more search. On the contrary, the study of the behaviour of "mutations," and of germ-cells in general, becomes more absorbing and interesting than ever. And so we now proceed to the work of the latest, though assuredly not the last, of the distinguished series of students who have made and are making our knowledge of heredity—Galton, Weismann, Mendel, De Vries, with his fellow-botanist, Johannsen; and Bateson, who is now beginning to be not without honour, even in his own country.

THE STRUCTURE OF THE TRUNK OF A TREE



This picture-diagram of a section through a three-year-old tree shows the various layers that go to make up its stem and ensure the stability, growth, and nourishment of the tree. The arrows indicate the course of nourishment from leaves to roots and roots to leaves.

GROWTH OF ROOT & STEM

The Different Forms and Adaptations of Roots and of Stems—Climbing, Twining, and Woody

THE THRUST OF LIFE TOWARDS FOOD

We have now discussed the structure of the simplest form of plant that one can imagine—namely, a seedling. We have further noticed how nutrition is carried on in plant life generally, and the source in Nature from which the plant derives its different nutritive materials. And, again, we have seen that this search for food on the part of the plant is not limited to providing for present needs alone, but that it includes preparations for accumulating a sufficient store of food for future necessities. These necessities are of two kinds. In the first place, food is stored up so that the embryo in the seed may have something to fall back upon before it can provide for its own requirements; and, in the second place, food is stored up to enable plants which live for more than one season to utilise a reserve supply during the months of physiological inactivity.

In a previous chapter we observed in some detail exactly how the seedling made its appearance, and we are now, therefore, in a position to devote our attention to what we may term the physiology of plant life; in other words, how plants carry out the different vital functions upon which their existence depends. These functions are very much the same in both plants and animals; it is only the means whereby they are effected which differ very markedly. The two primary functions of plant life—apart altogether from reproduction—are the questions of feeding and breathing; and it is to the successful carrying out of these forms of cell activity that most of the structures in the plant are devoted. The question, therefore, which now arises for our study is—how do plants feed and breathe? This resolves itself into an examination of the structures known as roots, and stems, and leaves, and used in feeding and breathing.

The careful reader will recollect that these three elements are precisely those which first of all made their appearance in the developed seedling. The radicle emerged from between the cotyledons, and grew downwards, in evident anticipation of the structure and function of roots. The plumule grew upwards towards the surface of the soil, in evident anticipation of the structure of the stem and all its parts. And in some forms of seedlings the cotyledons themselves took on the form and appearance of green leaves; so that root, stem, and leaves may be considered as the primary formation of the parts of a plant. These parts, as a matter of fact, are commonly present in all flowering plants.

The primary root of any plant is the ultimate growth of the radicle from the embryo, which, as we have seen, takes a downward course in the soil, growing by means of the cells at its extremity. This growth, however, does not extend indefinitely in this direction or in this manner, because after such a primary root has extended for several inches we may observe that it begins to give off branches, having a somewhat similar appearance and structure to itself, only upon a smaller scale. Moreover, these branches do not grow downwards, but, coming off at right angles from the primary root, they extend laterally, growing, as does the former, by means of the cells at their extremities. These lateral roots are termed secondary. In their turn, as growth increases, they give off still further branches, growing out obliquely from themselves, and these may be termed tertiary. So this subdivision of roots goes on until we may get a very complicated system, the whole arrangement being termed the root system of the plant.

The oldest roots amongst the primary ones are those which arise nearest to the original position of the cotyledons, and the

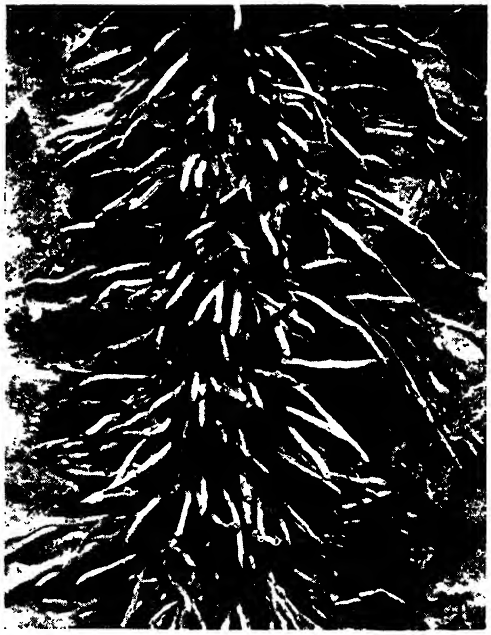
youngest are those nearest the tip of the primary root, these positions enabling one to determine their relative age. Moreover, they take their origin from within the primary root itself, and are connected with its interior structure.

When the primary root continues to grow prominently, overshadowing in size and strength all secondary roots, we get what is termed a tap root, such, for example, as is found in the carrot, and many trees. When the root assumes a more or less irregular swollen appearance, it is termed tuberous, and is usually used as a storehouse for food. On the other hand, in many plants the primary root becomes quite overshadowed by the subsequent growth of the secondary and other branches; and when this is the case the plant, when pulled out of the ground, shows a complicated bundle of roots, all of which are very much the same size and shape, and are spoken of as fibrous roots. The common groundsel is an example of this.

In some other cases the primary root is only a temporary structure, and is succeeded not by branches arising from itself, but by new roots coming from the stem of the plant. Such a case is observed in the onion. Other roots, again, spring from the different parts of the stem of the plant, and even sometimes from leaves, and these are termed adventitious. Cases of this kind are found amongst most of the farm plants—for example, in wheat. As we have seen, the embryo of the wheat plant has only three roots, and these are merely of temporary service, being succeeded, by the time the leaves are appearing, by a number of adventitious roots, which take their origin from the lower part of the stem. These adventitious roots, too, are found arising from underground stems, as is excellently seen in the mint plant. The potato is another example of the same thing. They also arise from runners, as in the strawberry plant.

All these adventitious roots are apt to occur at the joints in stems, in the same position at which leaves arise, and their appearance is commonly decided upon by the environment; that is to say, so long as the stem is in the air they do not show themselves, but should it come in contact with the soil with sufficient moisture, then they quickly grow. They may, however, arise apart altogether from such circumstances. Nothing is more curious than to observe that these adventitious roots can be made to grow from almost any part of certain plants; and so widely is this recognised that, as a matter of fact, the methods of propagation of many species are determined by this principle. All that is necessary is to take a number of cuttings and place them in the ground, when, climatic and other conditions being favourable, a number of young adventitious roots will make their

THE FIBROUS ROOTS OF GROUNDSEL



THE ADVENTITIOUS ROOTS OF IVY

7,887

appearance, and secure food to keep the cutting alive, and ultimately produce a new individual. This is the common way of propagating gooseberries, currants, roses, etc. Such adventitious roots are nearly always of the fibrous nature. Rarely do we find them assuming the tuberous form seen in the dahlia.

Having been produced in the way above described, the roots of plants and trees spread themselves out in various directions in their search for food; and an example of an uprooted tree will soon show the observer that the growth directly downwards does not extend for any very great depth. As a matter of fact, but few trees send their roots more than a few feet into the earth. On the other hand, there may be very great extending in the horizontal direction. This is obviously because at a certain distance in the soil the root comes to a region where there is neither moisture nor suitable food. Indeed, the deepest parts of such roots are more for purposes of fixation than nutrition. The latter function is carried on chiefly by means of the fine, small rootlets which arise all over the secondary and other roots, and which are broken off when a plant is pulled out of the ground, their number, on this account, not being readily appreciated.

The condition of the soil will obviously have a considerable effect upon the character of the growth of the root system, apart altogether from the kind of plant concerned. The stiffer the soil, the more compact will be the root system; and, on the other hand, in a very loose and sandy ground the roots will spread far and wide Adequate manuring, too, produces an extra supply of roots, so long as this is not carried to excess.

The different kinds of root, associated with different species of plants, call for close attention on the part of the grower, in so much as the method of tilling the

THE LATERAL GROWTH OF THE ROOTS OF A BEECH-TREE
Owing to the hilly situation on which this tree stands, the soil round the roots has fallen away, leaving the root structure bare.

ground, or preparing it, will have to vary considerably to meet the kind of root system in each case. Roots which go to considerable depth will obviously require that the soil should be worked in proportion, whereas roots which are mainly of the surface type can be dealt with on a soil of a much thinner character.

Perhaps the most important structures of all in connection with roots are those which are termed root hairs. These are not found at the extreme of the growing point, but at a short space behind it. They are always found in this position, and they occur not only upon the primary roots but upon the secondary and other roots, as they make their appearance. They are most plentiful on roots in a moderately damp situation. Their structure is that of hollow tubes, and they are actual outgrowths from the body of the root itself. They have a most fundamentally important function in the physiology of the plant—namely, to absorb from the surrounding soil the water which is required for the cells of the plant, and the dissolved materials in it. They come into closer contact with the soil than any other parts of the underground structures, and are destroyed when a plant is torn up. They are so delicate as to be almost impossible to be seen with the naked eye, and yet are not less important than any part of the plant. Everything that the plant gains from the soil reaches it through these root hairs. Only through them can moisture be taken in, and all that moisture contains. (See illustration of root hairs.)

EARTH CLINGING TO ROOT HAIRS

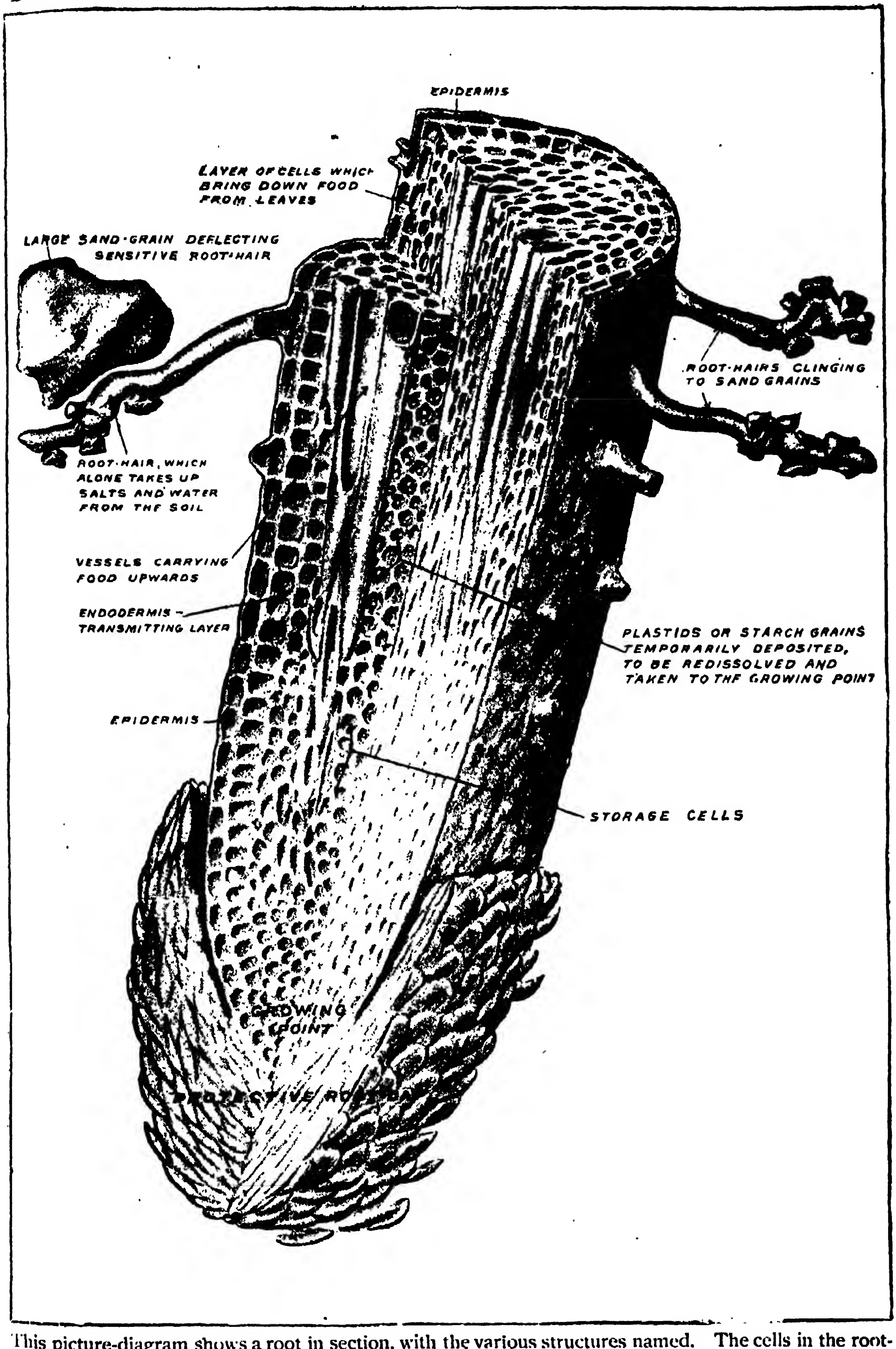
The actual process by which these root hairs are enabled to transport the water and the soil into the tissues of the plant is that which we have already studied under the name of osmosis. (See the lower picture on, page 546.) It is only those cells on the root hairs which come into actual contact with the particles of the soil which do this work of absorption. The rest act as conductors They move in such a way as to suggest that they are searching for the most favourable places where this absorption can take place, thus penetrating into the small places in the soil in which moisture is found. Should they come to a particularly dense part of the earth, or a solid portion, they turn aside and grow round it. If they encounter large grains of soil they sometimes divide, growing round the grain, and, as it were, embracing it. The minute particles of the earth are found attached to these root hairs, and this attachment is produced by a sort of sticky secretion of the external layer of cells on the root hair. Not only, however, do these root hairs act as organs of absorption for the plant, but they are also organs of excretion. Thus carbonic acid passes out from the plant through them into the earth.

A YOUNG IVY-CUTTING ROOTING IN WATER

It should be carefully noted that these hairs can only do their work in moist ground; and whenever the branches of roots have to make a choice, as it were, between a dry and a moist portion of ground, they invariably grow towards the moist part. This simple fact accounts for the many curious bends, and turns, and changes of direction which can be seen in almost all roots when they are exposed. An examination of any sufficiently deep cutting in the earth will show numerous examples of this fact. The root hairs are constantly perishing and being renewed, and always do they arise about the same distance from the growing tip of the root. They are the more abundant in plants which transpire readily, because in such plants there is a greater necessity to keep up the supply of moisture.

The root, the stem, and the leaf are the three essential parts of the plant in connection with the physiology of feeding and breathing. We have discussed the part played in this function by the root, and we must now turn to the consideration of the second of these structures—namely, the stem, since the stem might be defined as that part of the anatomy of a plant which communicates between the

THE BUSY FACTORY WITHIN THE ROOT



This picture-diagram shows a root in section, with the various structures named. The cells in the root-hairs absorb the moisture from the soil by the process of osmosis, and also secrete carbonic acid, while the cells within the root act as conductors for carrying the food through the plant and for storage.

root and the leaves, and enables them to work in harmony. It has also, of course, the very important function of elevating the leafy portion of a plant above the surface of the soil into the open air and sunlight, under which conditions alone leaves can best perform their work. The origin and the development of the stem we noticed in connection with the seedling. We must now learn something of the various appearances of stems and their structures, just noting in passing that there are certain groups of plants which have so evolved as to be practically destitute of anything in the nature of a stem at all. These so-called stemless plants find examples in the common dandelion, the white clover, and many others, which lie close to the ground. This stemless character obviously makes for the protection of the plant, especially from animals which would otherwise feed upon it. Such plants can even be trodden under foot without suffering any very serious injury, and they are therefore enabled to withstand the struggle for existence under conditions which plants with long stems could not resist. As a matter of fact, however, they are not really stemless, but their leaves and flowers come off from a very short stem which scarcely emerges from the soil.

Nevertheless, it is true that for the best performance of the functions of plants with a complicated structure some form of stem is required, and many and varied are the modifications found in the stems of plants to enable them to do their work under the different conditions in which they find themselves. True, the dandelion and the violet can flourish close to the ground, but most plants require to get some distance above the surface of the soil for their best development, and, indeed there is evidently a keen competition amongst many plants to secure the most elevated place within reach. This gives the leaves the maximum of light and air. If plants be crowded together, one can easily observe the effort made on the part of the stem to carry its leaves as high as possible; and in thick woods and forests where the surface of the ground is always more or less in darkness, we find this principle carried to its limit in the tremendous climbers and creepers which, throwing their growing stems from one branch to another, may extend for immense distances before they finally appear at the tops of the trees, and reach the air and light.

It is these climbers and twining stems which best illustrate the special means that stems adopt for their purpose. Three

BUCKSHORN PLANTAIN GROWING ON A FOOTPATH, HEEDLESS OF MAN'S TREAD

points attract the attention. First, they produce adventitious roots at intervals along the stems, which are used as anchors to support the stem in its progress so far on its upward journey. These roots attach themselves to any suitable object that will retain the stem in position. Our own ivy plant exemplifies this as it grows up the side of a wall.

Secondly, an effort is made to fix the growing stem by means of special twining branches, or tendrils; and, thirdly, in some cases the entire stem twists about or round and round any supporting structures it can find, as is seen in the case of the hop.

originates from the stem, thus acting as a spiral spring and drawing the whole stem to the point where the contact of the tendril takes place. This interesting arrangement may be seen in the bryony plant.

In the case of twining stems, the end of the stem, which is growing continually, revolves in a more or less circular manner, until it—just as the tendril did—finds some supporting structure around which it can coil. This is one of the most extraordinary examples of actual movements in plant structures that we have. It is excellently seen in connection with the hop plant,

THE TWINING BINDWEED

THE TWISTING STEM OF HONEYSUCKLE

Some of these special forms of stems offer most interesting points for the student of plant life. Thus we find that in those which climb by means of tendrils the tips of these structures move about in the air in various directions until sooner or later they reach something they can lay hold of. They then proceed to coil themselves round this support. The stem goes on growing, and another tendril goes through the same performance, and thus the stem is anchored at various points. But, still more remarkable, the tendril, having coiled itself round its own point of attachment, may then grow into the form of a spiral coil between that point and where it

which, after twining itself round and round the pole which has been placed in the ground for that purpose, continues to make this circular sweeping movement after reaching the top of the pole. The circle so described by the twining stem is about two feet in diameter. Another plant commonly seen in greenhouses, and known as the wax plant, moves in a still greater circle, of about five feet, and the tip of the stem can be calculated to move at the rate of about two and a half feet in the hour.

We may further note the fact that the same species of plant always twines round its support in the same direction. This direction, however, is not the same

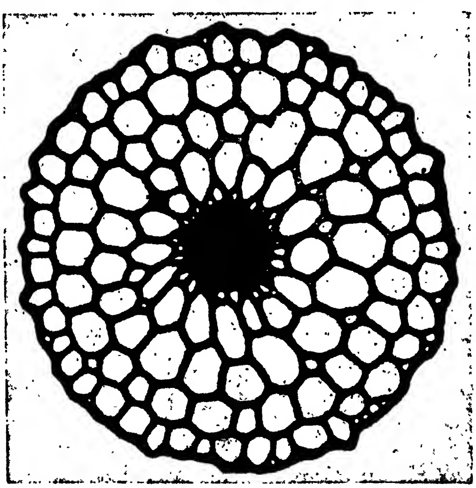
necessarily in all species. Some of these tendrils are modifications of the leaf, an example of which may be seen in the pea, where the terminal leaf, instead of being the usual green structure, is modified into a tendril—hence called a leaf tendril—very sensitive to anything coming in contact with it, and readily coiling itself round any available point of attachment. In other cases the tendrils are modified branches of the plant itself, and this we see in the vine and in the Passion-flower.


THE LEAF TENDRILS OF PEAS

The following is a short summary of the different kinds of stems usually found. The herbaceous stem is the stem of most of our annual plants, as well as of many perennials. It is a soft structure, lasting for a comparatively short time. Stems of a more permanent growth must become very dense in consistence, and this they do by producing true wood, and so are termed woody stems. Herbaceous stems are also composed of wood, but in them it is small in amount in comparison with the softer parts. The distinction between these two is really one of age, not of kind; it is a question of development. Thus a stem may be herbaceous in its upper parts and woody in its lower, as we find in the wallflower.

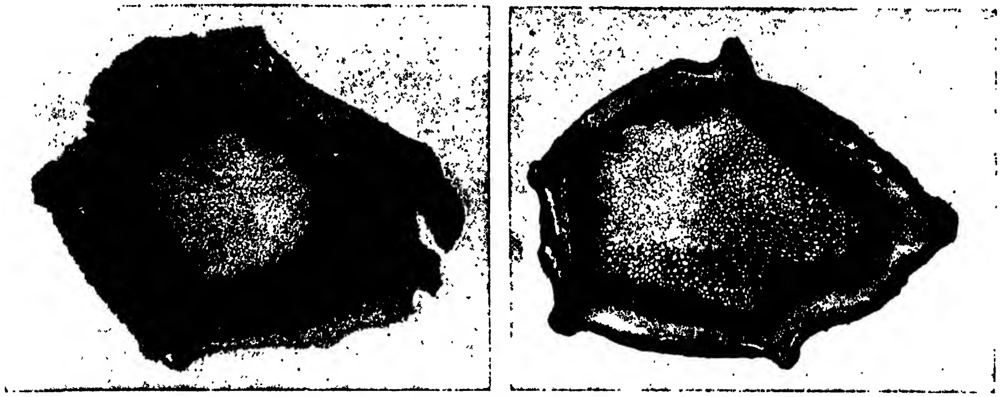
A well-developed stem of the woody type, lasting for a considerable time, is termed a trunk, such as is found in trees and shrubs. The difference between these two is really one of branching, the tree trunk being free from branches for a certain distance above the surface of the ground. Its woody stem is a prominent feature. The shrub, on the other hand, does not show a very distinct main stem, and its branches, arising low down, are very much of the same size. If the stem is insufficiently strong to raise itself into the air, it is termed prostrate, while if it develops means of supporting itself in other ways it becomes a climbing stem. These supports, as we have seen, are of various kinds, generally termed tendrils, arising either from the stem itself or from modified leaves. Of the latter kind we have the common tropæolum, the clematis, the peas, and the vetches. In the case of the twining stem it should be remembered that it is the whole plant which is coiled round the support. The hop coils to the right, the bindweed to the left.

It is unnecessary here to enter into very minute detail of description concerning the intimate structure of roots and stems. The illustrations in this chapter have been prepared in order to show these points, and a careful examination of them will give the reader a better idea of their intimate structure than mere description.


SECTION OF MARESTAIL, SHOWING OPEN STRUCTURE OF STEM

We have only further to consider at this point what the living parts of the stem actually do, and how the labour of the whole stem is divided amongst them. This is best studied in the stems of trees. The pith, which forms so large a part of the stems in younger portions of plants, becomes comparatively unimportant later on, though it serves a purpose as a food storehouse. The medullary rays in shoots are the passages along which the moisture and the dissolved food are transferred across the stem, and they also contain stored-up food. The vessels, or channels, in the stem are mainly water-passages up which the moisture travels. The hard, dense portion of the

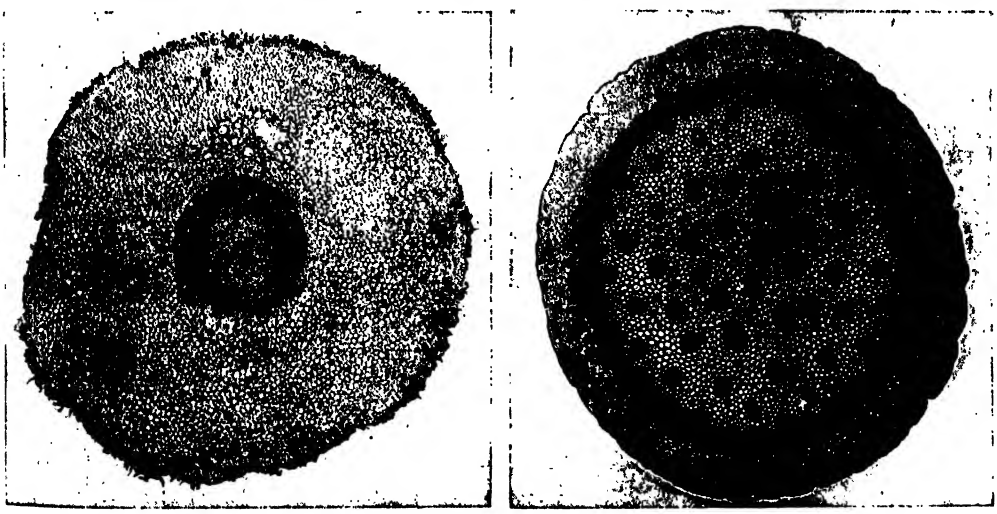
heart of the wood serves the function of maintaining the erect attitude of the tree in virtue of its density. Other cells in the sap-wood, which also helps to support the tree, in addition carry water from roots to leaves. The layer of cambium is that in which new growth takes place every year. of the tree, and rises in the form of crude sap through the newest part of the wood. As a matter of fact, there is both an upward movement of sap, and, in addition, lateral transportation of the fluid from one side of the stem to the other. The causes of these modifications of water or



TRANSVERSE SECTIONS OF THE SOFT AND HARD PARTS OF THE STEM OF A WALLFLOWER

But the most important part in connection with the inside of the bark is that in which lie the sieve-tubes. It is through these that the digested food for the plant is transferred from the leaves in the direction of the roots. Much of the nutrient material in the growing portion of the stem fluid in the stem have been dealt with in connection with the process of osmosis and the phenomenon of root pressure.

All the most important points in the foregoing paragraphs will be found to be easily understood if a careful examination be made of the illustrations in this chapter.

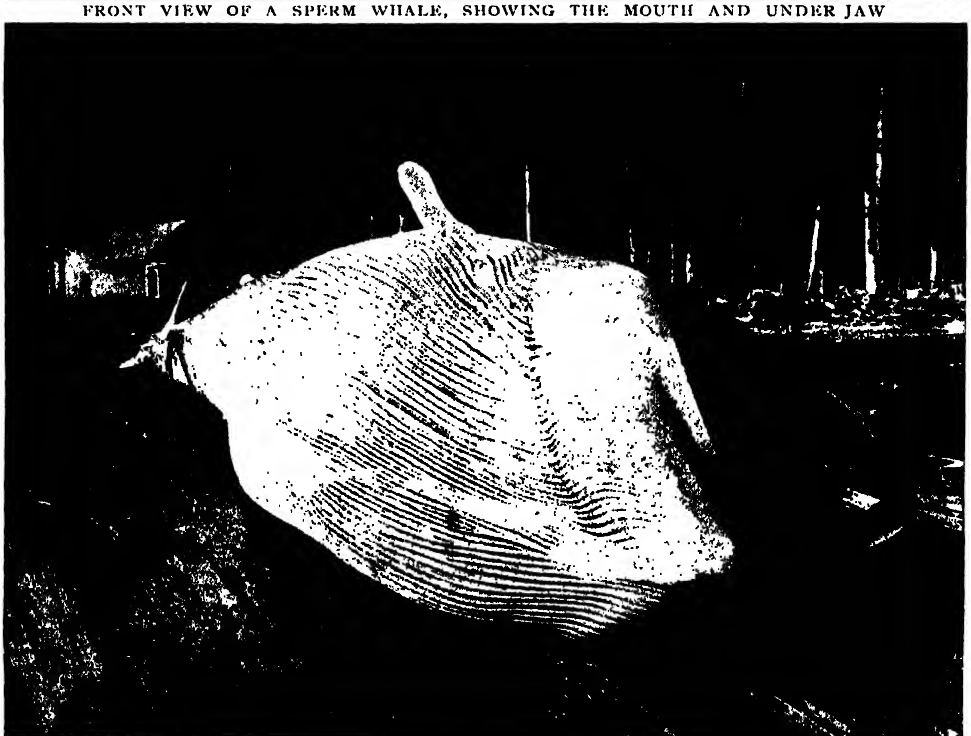


TRANSVERSE SECTIONS OF THE ROOT AND STEM OF BUTCHER'S BROOM

is collected by the green layer of the bark, but this process we shall have to consider in connection with leaves in a succeeding chapter.

A considerable amount of water in the form of sap moves by the process of osmosis from the root hairs into the stem We would especially draw attention to those which show the different kinds of roots and the way in which the minute particles of earth cling to the root-hairs to which they yield up their moisture and other nutritive elements. The other pictures show how these elements are transported.

FRONT VIEW OF A SPERM WHALE, SHOWING THE MOUTH AND UNDER JAW



AN 80-FOOT SIBBALD'S WHALE, THE LARGEST SURVIVING ANIMAL IN THE WORLD

MAMMALS IN THE WATER

The Strenuous Life of Land Animals that Have Become the Monsters of the Seas

THE STRANGE TALE OF PELORUS JACK

FEW types of animal life present a greater puzzle to the non-student of Nature than the water-beasts we have here to consider—the whales, the sirenia, and so forth. Glancing at the question for a moment, the observer assumes, perhaps not inexcusably, that they are great fish—whales the largest of all fish, the sirenia (that is, the manatis and dugongs) their smaller kin. And upon this assumption he must take it for granted that these " fish " have always been denizens of the waters, and have developed from other fish. What a surprise it must be to such a man to learn that the whale is as truly mammalian as the human species! That it is hot-blooded, brings forth its young alive, suckles its young as a cow suckles its calf, cannot breathe under water, and that, should it be prevented from rising to the surface to renew its supply of oxygen, it would drown! This is true of whales and dolphins of every species, and equally true of the sirenia.

Corrected on these points, the non-expert may be forgiven if he cling to error and say: " Well, these are surprising developments of fish life! " It is not unnatural to regard these creatures, mammals though they are, as having arisen from fishes. Birds were reptiles, which are the remote ancestors of mammals also; there would be nothing more surprising in the discovery that whales and sirenia had been evolved from fishes But although the cetacea and the sirenia have attained full development in the water, they did not originate there. There were whale-like ancestors which, after ages of carnivorous feeding upon the margin ot ocean and river, produced offspring that put out to sea and did not come back. And the same is true, in a way, of the sirenia. Neither whale nor manati nor dugong could now make a living on the land; their food and dwelling-place are both in the waters. But all are the descendants of land animals. Yet there is no more relationship, except that both are mammals, between the sirenia and the whales than between sirenia and the man in the moon.

One of the richest and rarest prizes of the palæontologist has been dug up in the Fayum province of Egypt, where the ancient history of these animals has lain many ages hidden. In a great depression in the Libyan desert, fed by the overflow of the Nile and by a river now vanished, a huge collection of primitive mammals anciently made their home, and there unwittingly bestowed, in their bones, one of the most fascinating and astounding legacies that has come down to man of the present age. For there, in those age-old bones, unearthed within recent days, are the unmistakable links between the water mammals of our own day and the land fauna of prehistoric æons. And from these the surprising genealogy of cetacea and sirenia is clearly deduced. The whales are the descendants of ancient land-haunting carnivorous mammals known as the Creodonts. The manatis and dugongs derive from an ancestry whence the elephant and the little hyrax, or coney, branched off.

Of course, all external trace of their association with life on the land has been obliterated from the anatomy of both types of animal, but the sirenia retain the characteristic head of the terrestrial mammal. No member of the order has developed the back-fin common to many of the cetacea. In both, respiration is highly specialised, as in the crocodilia, to enable the animals to swim beneath the surface with mouth open without water entering the lungs. Although the fact is not obvious from superficial appearances, both orders have the same number of vertebræ in the neck as other mammals; the short, imperceptible

neck of the huge whale has as many vertebræ as that of the giraffe and the rabbit. Both whales and the sirenia retain, hidden within the thick, fleshy flappers, their four or five fingers, but only vestiges of the hind limbs with which their ancestors once roamed the earth are now to be discovered. There is one peculiarity common to the sirenian and the dolphin tongue: each is furnished with curious pits or depressions, in which the presence of numerous ganglionic cells suggests a connection with the sense of taste.

For the sake of one of Matthew Arnold's most charming poems it is a pity that manatis and dugongs are such unlovely beasts. For these are the "mermaids" and "mermen" of old seafaring legend upon which poet and story-writer have fastened. Dull, heavy, almost repulsive-looking case with the tails of fish. In place of features resembling the human, the sea-cows have heavy, bristly jowls, with nostrils set at the apex of a triangular-shaped muzzle, and those nostrils are fitted with valves which enable the animal to close them against the intrusion of water when diving below the surface.

The manatis have the tail rounded; that of the dugong is crescent-shaped. In the manati the upper lip is prehensile, and becomes the grasping instrument by means of which leaves and other vegetable food are introduced into the mouth without the assistance of the under lip. To effect this purpose, the upper lip is divided into two fleshy pads, which, on being brought within reach of food, at first diverge, then close upon the object, firmly seizing and securing it. The action of this lip is likened to the

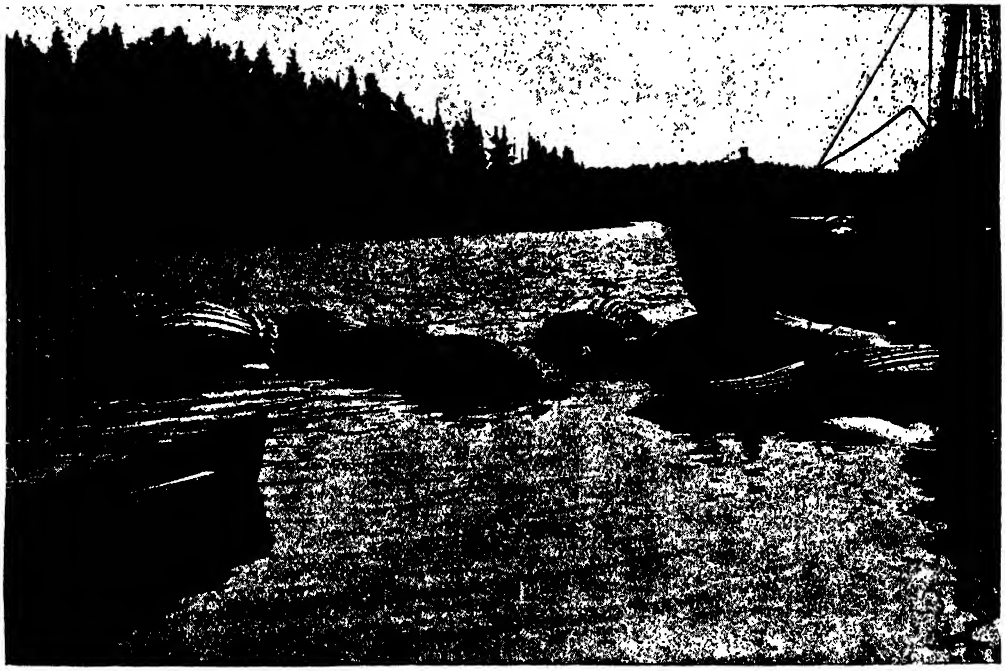
CAPTURED WHALES MOORED TO THE STERN OF A NORWEGIAN STEAMER OFF SPITZBERGEN

animals, how came they to be thus idealised? The sea-cows—such being their popular description—have the teats high up on the breast. When suckling her young one, the female raises her head and breast out of the water, and, supporting her calf by means of her flippers, feeds it. The action, witnessed from a distance, must have seemed human to early navigators, and they would bring home tales of water-dwelling women nurturing their babes in the midst of the waves. Poetic fancy would do the rest, albeit not all legends of mermaids represented the heroine as lovely. The glistening tail of the conventional mermaid is a figment of the fancy. Needless to say, no mammal has scales, and the tails of the sea-cows, like those of the whales, are horizontal not vertical, as is the action of the jaws of the caterpillar, in which there is a continual lateral opening and shutting during mastication. Manatis have their home in the rivers and on the coasts of the two sides of the tropical Atlantic, but are found mainly in rivers, some of which, such as the Amazon, they ascend almost to the sources. Their numbers have been sadly depleted, owing to the fact that their oil and hides have a commercial value.

The dugong, of which there is only one species, as against three species of manatis, ranges from Eastern Africa to Australia, from Ceylon to the Andaman and Nicobar Islands. It never ventures into rivers, but feeds upon seaweeds and marine grasses, but otherwise its habits differ little from those of the manati. Both animals attain a large size—from five to eight feet, with a

girth of six feet—and both are helpless on land. The manati would seem to be the more generalised animal, for it can live in salt water or fresh, but the dugong is said to find life impossible in any but sea or brackish water. Several extinct species of sea-cows have been traced, of which the Northern sea-cow, a very much larger animal than the existing species, and inhabiting far colder waters, was found in thousands on the shores of the Commander Islands midway through the eighteenth century. A single living specimen would be worth a fortune to-day.

When we come to the whale family we reach a group more ample than would at first sight appear. In it are embraced the dolphins, the porpoises, the grampuses; and whales such as the "sea-unicorn," which are whales only to the initiated, and the "black fish," which are not fish at all. The existing members of the group are an order to themselves, divided into two sub-orders, of which the first covers the whalebone or true whales, divided into five genera. The whalebone whale has no teeth, and has been regarded as derived from a source different from that which gave rise to the toothed whales. But before birth the embryo whale has two sets of teeth, corresponding with the milk-teeth and permanent dentition of other mammals. Those of the earlier set are absorbed into the jaw before the birth of the animal. They present characters resembling the teeth of the zeuglodonts, the extinct, semi-armoured, whale-like animals through which we trace the descent of the existing order. In the baleen whale the nasal aperture is double, as in other mammals, but in the sperm-whales it is a single orifice.



A SCHOOL OF HUMPBACK WHALES AT A STATION

The whale is one of the most striking examples of special adaptation to a particular mode of existence. It is the finest "submarine" in the world. The human diver with the best of equipment, can work with difficulty, and at the risk of paralysis, at a depth of 160 feet or so below the water. At that depth he bears a pressure upon the body of about 70 pounds to each square inch. Now, there is fish life in the sea that can exist only in the middle depths, and is crushed by pressure if forced down into the depths below its habitat. These same fish, brought to the surface, burst like pricked bubbles. But the whale is known, after coming up to breathe, to descend perpendicularly nearly 5000 feet. At that depth a large whale must sustain a pressure of close upon 140 tons on every square foot of its body. It swims from Polar seas to tropical, the heat of its body conserved by the enormous blanket of blubber wherein it is invested, and that blubber serves also,

it is assumed, to enable the animal to withstand the enormous water-pressure it has to endure.

The distinguishing feature of the baleen whale is, of course, the baleen or whalebone which in these animals takes the place of teeth. This baleen consists of horny plates, frayed at the edges into a kind of fringe. These plates, arranged along the two sides of the upper jaw, vary in size, being shortest at the front and back of the mouth, and at their greatest length—some 10 to 12 feet—along the centre reach of the arched jaw. When the mouth is closed these plates of baleen lie flat along the jaw, with the points directed towards the throat. When the mouth is opened the plates are automatically erected, the principle of mobility being the same as with the fangs of the snake. Now, this huge mass of baleen, which in the Greenland whale may number close upon 400 plates to each side of the jaw, and weigh from 10 hundredweight to 30 hundredweight, is simply the vast sieve wherein the whale entraps its food. The jaws may be twenty feet in length, and are thrown wide open as the animal swims into a swarm of teeming crustaceans and molluscs floating upon the surface of the water. The jaws close upon a vast volume of water in which multitudes of these small animals are swimming. As the jaws come together the water drains out at the side, but the life that it contains is enmeshed in the whalebone strainer, and directed towards the throat. Thus this monster of the deep—fifty, sixty, and more feet in length, and weighing many tons—feeds upon quite minute forms of life. A shark can swallow a fair-sized sack of coke, but a "right" whale would strain at a sprat and choke deplorably over a herring.

The black whale, or Nordcaper, is a smaller animal than the Greenland; it is more active and makes a fiercer fight for life; but from Norway to Japan, from Australia to Spitzbergen, it is remorselessly hunted, as indeed the members of the whole tribe of whales are, and these aquatic mammals are among the doomed animals of the world. The black whale carries a puzzle upon its head—a series of horny, honeycombed excrescences known as the bonnet. This bonnet was believed to be created by the whale's scraping its nose against rocks to rid itself of the barnacles that infest it. But, inasmuch as the cells of the so-called bonnet are found to be filled with whale lice, which are, in fact, crustaceans of the genus Cyamus, and these crustacea prey upon the larva of barnacles, the origin as well as the purpose of the bonnet may have been misjudged. That the excrescences with their cells came into being as an asylum for lice to police the hide of the whale against its enemies is hardly seriously to be asserted, but many mysterious processes are reflected in the story of inherited tendencies.

A HERD OF BOTTLE-NOSED WHALES CAPTURED OFF THE SHETLAND ISLANDS

Sandwiched between the Nordcaper and the big grey whale we have the pigmy whale, but we must not infer from the name that here is something to be added to the list of possible pets for the artificial salt-water lake; the pigmy whale averages from 15 to 25 feet, rather less than half that of the grey whale. The latter, confined now to the North Pacific, is represented in superficial deposits in the British Isles, its bones mingling with earth where once deep waters flowed.

Much the same proportions are attained by the humpbacked whale—a name that relates to the massy prominence on the back of the whale by which the fin is supported. This whale has a wide distribution, and is a frequent visitor to British shores. It is hunted everywhere. The results of the chase are somewhat of a lottery; for whereas the biggest yield of oil may represent as much as seventy-five barrels, another whale will produce but an eighth or ninth of that total.


A WHALE IN THE ACT OF FEEDING


A WHALE ABOUT TO DIVE


A HUMPBACK WHALE WITH NOSTRILS FULLY EXPANDED IN BREATHING

Next to the humpback come the rorquals, or fin-backs, of which four species are recognised. They are the commonest of all whales. The fact that they produce only the coarsest and shortest of whalebone and the smallest quantity of blubber may be not unrelated to their comparative immunity in the past. But, on the principle that half a loaf is better than no bread, the whale-hunter has of late turned his attention more closely to this whale, and by better organised methods of chase and commercial processes has brought it more prominently into the profit-yielding items of his balance-sheet.

The rorquals are less restricted in the matter of swallow than the Greenland whales, subsisting upon fish such as the herring and pilchard. These, not worth swallowing in twos and threes, are received into a large collapsible pouch in the throat until the requisite cargo has been collected, when the whole are swallowed together. It is the lesser rorqual which, gambolling about moving ships, is commonly mistaken for the young of the greater whales. But an adult lesser rorqual ranges between 25 and 30 feet, with occasional examples of greater size. The common rorqual, however, varies between 60 and 70 feet. The immense speed and strength of this species kept them moderately safe until latter-day modifications of whale-hunting equipment trebled the effectiveness of man's attack. But it is the next species, the blue rorqual, or Sibbald's fin-whale, which claims pre-eminence for size. This is the veritable leviathan, 70 to 90 feet in length, and of bulk proportionate. It is the largest living animal in the world, and until the advent

of explosives in the chase held its own pretty well against its human enemies.

Passing now to the toothed whales, we note first the huge sperm whale, or cachalot, which rivals the Greenlander in size, and is an incomparably more formidable animal. The baleen whales are quite inoffensive creatures, never dangerous to man save when in their death throes, and then only by the violence of their agony, in which they may involuntarily overturn a boat. The sperm whales, however, are more militant, as is perhaps to be expected of animals armed, as to one jaw, with the most formidable array of teeth. In former days both jaws of the sperm whale were furnished with teeth, but the existing species never develop more than vestigial evidences of dentition in the upper jaws. The sperm whale is the giant of all the toothed cetaceans, weighing, for a 60-foot specimen, about 70 tons. These monsters are, of course, becoming more rare. So merciless is the persecution to which they are submitted that they are vanishing from the waters to which the stress of competition so long ago drove them.


THE TAIL OF A DIVING WHALE

The cachalot is a native of warm seas, but in summer may roam far north. It is a great traveller, as is evidenced by the fact that specimens have been taken in the Atlantic still carrying the harpoons discharged into their bodies while they were in the Pacific. The female produces one young one at a birth, but that infant may measure from 11 to 14 feet! The female cachalot displays great solicitude for her young, as, indeed, do all female whales, and evinces also a good deal of intelligence in protecting them. How the cachalot procures its food cannot be told, as the animal feeds deep beneath the surface, but the nature of its diet is known. Although considerable quantities of fish are taken, squids and cuttlefish constitute the chief source of the monster's meal. Tremendous combats between cachalots and giant cuttle-fishes have been witnessed. Cuttle-fish, huge and hideous enough to challenge comparison with the most fanciful pictures of the old writers, have been seen madly grappling the titanic bulk of a whale, the terrible tentacles, like a series of colossal boa-constrictors, seeking to crush the enemy. But the whale evinces no apparent discomfort; he simply eats his bonds one by one. It is only by hunting the cachalot that we can arrive at an estimate of the dimensions of these fearsome cuttles of mid-ocean. The whale, when mortally wounded, disgorges its last meal, and at such times pieces of the arms of cuttle-fishes six feet in length and eight feet in circumference have been recovered—a significant suggestion as to what must have been the full dimensions of the unmutilated cephalopod.

Ordinarily the sperm whale is quite harmless until attacked. Even then the first impulse of the animal is to seek safety in flight. But it is at such times that danger is to be apprehended, for when wounded the animal, with tail or jaws, will attack and smash everything within reach, and, after flinging boat and men into the air, will chew the timber of the wrecked boat into matchwood. Not a few instances are on record of cachalots having attacked ships. A singular example comes from Australian waters where a brigantine, deeply laden with timber, was assailed by two cachalots. At the last moment one of the animals shirked the unprovoked combat, and dived. The other tilted head-on at the ship, and struck with its head such a blow that the vessel was caused to reel from stem to stern and had its side smashed in. But these are, after all, exceptional cases, and the sperm whale is a long-suffering animal.

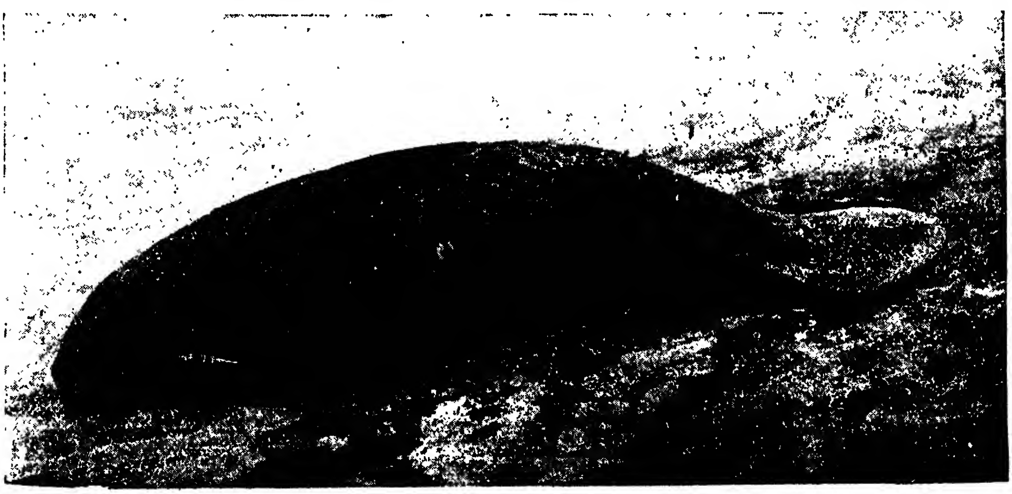
Although it lacks the inestimable baleen, the cachalot is a precious harvest to its captors. It yields the little-understood ambergris, which, sometimes found floating upon the water, sometimes in the body of the animal, is worth £4 10s. per ounce. The more dependable profits, however, are the blubber and spermaceti. The latter occurs in enormous quantities in a huge cavity at the back of the head. After treatment it

THE DUGONG, THAT GAVE RISE TO THE LEGEND OF THE MERMAID

becomes superfine candles for altar and shrine; it salves our hurts when made into cold creams, ointments, and the like. The blubber, rendered into oil, accompanies us into the bath, in the form of the best soap.

The sperm whale is not alone in yielding these substances; there are other whales—the bottle-nosed and beaked whales of various species which are made to contribute their quota. The bottle-nosed whale, which yields a finer oil than the great cachalot, is even more persecuted than some of its fellows, and is now swiftly verging upon extinction. Many female whales stay by a wounded companion, but this solicitude extends to both sexes of the bottle-nose. A herd is easily approached by a ship, and when one is wounded the remainder swim round it in great concern, so that one after another can be attacked in turn until the entire school is killed.

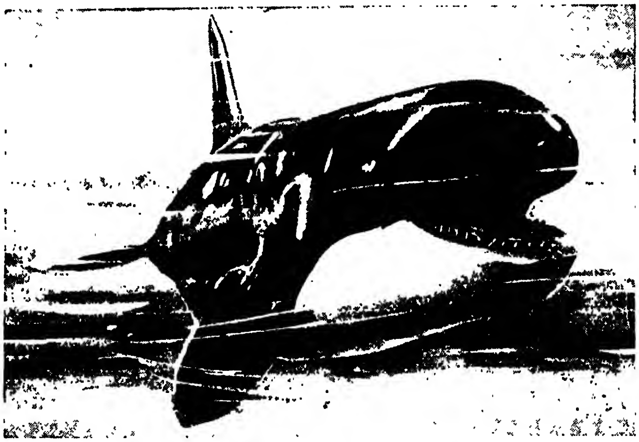
Men have been hunting the whale for a thousand years, and it is computed that in that time a million victims have been secured. But latterly the calling has become more closely organised, and the hunting keener than ever. Shore stations have sprung up in all directions, where blood, bones, and flesh, as well as blubber and spermaceti, are utilised. From the point of view of the trader the change is excellent, but the Nature student cannot but view with deep regret the seemingly inevitable extinction of these leviathans of the deep. Unless someone unmindful of the scorn of those who deem it affectation to pity a whale make a stand for these animals, as for seals and sables, the day will come when



A YOUNG MANATI, CAPTURED AND LEFT STRANDED

the seas will no longer know their ancient monarchs.

The toothed whale sub-order, as we have noted, is an extensive one, and some of the groupings may seem a little curious, for among the porpoises we have the narwhal (or sea-unicorn), the killer whale, the beluga (or white whale), and the black-fish (or ca'ing whale). The first named is that curious creature which has converted the tusk on the left side of the upper jaw into a massive spiral weapon of offence and defence, yet remains toothless. This abnormal tusk, which is of dense ivory, and may measure from 7 to 8 feet, with a circumference of $7\frac{1}{2}$ inches at the base, is believed not to be employed in securing prey, but in combat, after the fashion of the antlers of the deer. The beluga yields a good leather, which is commonly sold as porpoise-hide.



THE KILLER WHALE, OR GRAMPUS

The killer, or grampus, is the swiftest and fiercest of all the order, and the greatest glutton. Two or three combine to attack a Greenland whale, and devour it alive, darting into its mouth and eating out its tongue piecemeal, or tearing great masses of flesh from the body of the quivering victim, which seems powerless to resist the speedy and ferocious enemy. As killers attain a length of 20 feet, and, like all the family to which they belong, possess formidable teeth in both jaws, two or three acting in concert form a terrible combination. The killers do not confine their attentions to the whale, but are practically omnivorous. One has been seen to swallow four porpoises in succession, which is not surprising when we learn that the stomach of one which was killed was found to contain the entire bodies of thirteen porpoises and fourteen seals. The length of that grampus was 21 feet.

The bulk of the dolphin family are of marine habits, but some of them frequent rivers. The Gangetic dolphin, or susu, is essentially a river animal, inhabiting the Indus, the Brahmaputra, and Ganges from the sea right away up to the point at which the rivers quit the mountains, where they feed upon fishes and prawns, among the former being a number of mud-haunting cat-fishes which the dolphin probes out with his beak-like toothed jaws.

COMMON PORPOISES

The Amazon and La Plata have each their fresh-water dolphins, while in the Irawadi there is this peculiarity to be noted: in the upper waters are numerous representatives of a species (*Orcella fluminalis*) which never descend to the estuary, while in the estuary is a closely allied species (*O. brevirostris*) which never ascends the river beyond the influence of the tides.

Porpoises, which are grouped with the dolphins in one sub-family, are the commonest of all cetacean visitors to the British coasts, and are to be found at times high up some of our tidal rivers, both north and south. But the sea is

heir proper home, and three that were rapped by a fence thrown across the Wareham river in Dorsetshire some years ago are said to have uttered distressing cries day and night. The porpoise may readily be distinguished from the dolphin. It is smaller, and has a rounded muzzle without any suggestion of a beak.

Of several remaining dolphins one must be singled out for mention, Risso's dolphin, for to this genus belongs the most famous, and, indeed, the only famous, individual dolphin in the world. "Pelorus Jack" is a Risso dolphin, and is the subject of a special protective Order in Council issued by the New Zealand Government. Pelorus Jack is the self-appointed pilot of certain steamships which make the voyage between Pelorus Sound and the dangerous French Pass separating Durville Island from the New Zealand mainland. "Certain steamships," it is stated advisedly. The animal is shy of new steamers, showing himself with freedom only to those that he knows, and ignoring sailing-vessels. The latter point is peculiar. Whales ordinarily approach sailing-vessels with confidence, but are scared away by the propellers of a steamer. The case is different with Pelorus Jack. As a vessel known to him emerges from Pelorus Sound he darts from some unknown hiding-place, and, gambolling and leaping with every suggestion of joy, he precedes or accompanies the vessel to the mouth of French Pass. Here his duty ends. He does not enter the troubled waters of the pass, but returns to his home to await the advent of another vessel.

PHOTOGRAPH OF PELORUS JACK, THE RISSO DOLPHIN OF NEW ZEALAND

The obvious suggestion is that his act is prompted by the desire for food thrown from the vessel. But it is positively asserted that he does not feed when upon his journeys. He is known, from certain markings, to have been engaged upon this friendly mission since 1889. The late Mr. Seddon used to tell of two such dolphins swimming in company, but Pelorus Jack has for many years been sole pilot. A strange thing is that Pelorus Jack, venerated as a sea-god by the Maoris, forms the subject of wonderful native legends carrying us back to days of long ago. We know that Maori legend preserves for us the tale of the giant moa-bird, handed down from father to son since days when that extinct wonder lived in the land; and the supposition is that Pelorus Jack has had predecessors alleged to befriend man in days gone by. But the Maoris believe that the sea-god of their legends and Pelorus Jack are one and the same dolphin.

Once or twice, foolish, brutal tourists have tried to shoot Jack, hence the Order in Council specially protecting Jack and all his genus "in the waters of Cook's Strait, or of the bays, sounds, and estuaries adjacent thereto." Jack's career has not been without accident. In 1905 he was hurt by the bow of the steamer "Penguin," and for months after he was absent from his beat. He reappeared in time, but has ever since avoided the bow of the steamer. The scar caused by the blow is clearly visible today.

The Risso dolphin is known to feed on big cuttle-fish, and certain scratches and clawings upon the hide of the mammal are attributed to the tiger-like talons of the cuttle's suckers. Pelorus Jack is a cuttle-feeder; and there is this significant note in a recent description written by one who has seen and photographed him. "His colour is bluish-white tinged with purple and yellow, and with *irregular brown-edged scratch-like lines in all directions.*"

It is amusing to note that the New Zealand Government, having generously passed a law for the preservation of Pelorus Jack's life, are not quite certain of the order to which he belongs. "The fish or mammal," says their Order. Still, animal life would be in better keeping if we had many New Zealand Governments to pass equally exemplary regulations.

A GREAT BIOLOGIST AND PHILOSOPHER

ERNST HEINRICH HAECKEL, NATURALIST, WHO, AS A PROFESSOR AT JENA, GAINED THE EAR OF THE SCIENTIFIC WORLD FOR ALL HE WROTE

THE BEGINNINGS OF MIND

Is There a Soul in Every Cell of Life, and Is Sensation the First Expression of Mind ?

CONSCIOUSNESS THAT MAY BE EVERYWHERE

We must be certain to begin our study of the mind at the beginning, or we shall sooner or later have to find our way back to it, and start all over again. The very elements of mind are to be found, of course, in the mind of man, but he displays mind in such a high and complicated form that we can scarcely recognise the units of which his mind is made. We must, indeed, go much lower in the scale of mind. The beginning for chemistry, until a few years ago, was the atom, and the way to reach the atom was by beginning with the study of an element like oxygen, not with the study of some hugely complicated compound like hæmoglobin. So here we find that the units of the mind can best be discovered by the study of the simplest minds, instead of the most complicated mind of all.

Such a mode of inquiry leads us instantly to the evident truth that the beginning, or unit, or simplest portion of mind is sensation. We rightly speak of " that which knows," but that which knows must first be that which *feels*. If you have no senses, no " gateways of knowledge," you cannot know. Therefore sensation comes first. It is the absolute beginning of all the phenomena of mind. We may probably go further, with much truth, and say that a single, simple, pure sensation bears much the same sort of relation to mind in general as an atom bears to matter in general. There, at least, is a clear and suggestive idea worth remembering, and easily remembered. It helps us, by an image which we can readily understand, to see the fact of sensation in something like its true relation to mind as a whole.

This is undoubtedly the right beginning for our study of the mind, but let us beware lest we get our right beginning wrong. We only have to think for a moment of the laws of chemistry, and the manner in which atoms behave according to fixed laws—such and such combinations making white of egg or water, and all these combinations depending upon physical conditions like temperature and pressure, electricity, and so on—in order to say to ourselves: why should not just the same laws of physics and chemistry that apply to atoms, and therefore to all the phenomena of matter, apply also to sensations, and to all the phenomena of mind, which is built up out of sensations as matter is built up out of atoms ?

This is far from being a new idea. On the contrary, any logical attempt to establish the doctrine called materialism, which declares that all the phenomena of mind are the consequences of the phenomena of matter, must prove, if it is to establish itself, that the facts of mind—as, for instance, sensations—have absolute, mathematical laws, just like the facts of matter. Hence the celebrated introduction of the new " science " called *psycho-physics*, in the nineteenth century. The name implies, evidently, that there can be and must be a physics of the mind, and that we can reduce the working and behaviour of the mind to mathematical formulæ like the working and behaviour of stars, or chemical solutions, or explosives. This new " science " will remind the reader of another " science," which is of still more recent origin, but has already fared badly at the hands of Time—the science of " biometry," which tries to measure life, and reduce it to mathematical laws. Obviously the psycho-physics of the German materialists, and the biometry of the distinguished English materialist Professor Karl Pearson, are different forms of one and the same thing. Here it is incumbent upon us to examine psycho-physics, and to decide what our relation to it is to be for the future.

It began with the work of two celebrated German physiologists, leading representatives

of German materialism in the nineteenth century; and their names are commonly linked together in the celebrated "Weber-Fechner law," which is the basis of psycho-physics. This law is not too difficult to explain. Plainly, if mind begins in sensation, and if, as everyone knows, sensations differ in intensity, we must try to measure the intensity of sensations. Here is a field, and an absolutely legitimate field, for mathematics, which is essentially measurement. We throw a light into the eye, and feel the sensation of light. If the light be more intense, we feel a more intense sensation. So with hearing, or the sense of pressure, or any other. The light, the sound, the weight, whatever it be, is called a stimulus when it arouses a sensation. But the intensity of light or sound can be exactly measured, in terms of physical laws; and nothing is easier than to experiment, first with a weight of one pound, and then with a weight of two pounds. Ought there not, now, to be a definite relation between the intensity of what strikes us and the intensity of what we feel? We all know that there is some relation, for the heavier weight feels heavier, the brighter light arouses acuter sight-sensations, and so on.

The Attempt to Measure Sensation as We Can Measure Light

This fundamental question of the relation between the strength of the stimulus and the intensity of the sensation which it arouses was what Weber and Fechner set themselves to study. They obtained some extremely interesting and valuable results, showing how a certain minimum strength of stimulus is necessary before any of our sensations can be aroused, how the sensation increases in intensity when the stimulus increases, and how repeated stimulation—say, a series of little taps—will arouse sensation, though any one of those taps would not be felt or heard. Anyone can see that there is here an endless field for experiment, and we might devote chapters to results obtained in the study of any one of the senses along these lines. But what specially matters for us here is that these observations were declared to lead to a single, universal, exact, mathematical law, underlying all the operations of the mind.

This illustration will prepare us for it. If a light excites a sensation, twice as strong a light excites *not* twice as strong a sensation, but something rather less than that. How much less? When several and various observations had been made, some observers came to the conclusion that the rule is this: four times as strong a stimulus will produce only twice as strong a sensation; multiply the stimulus by nine, and you will intensify the sensation by three; multiply the sensation by sixteen, and you will intensify the sensation four times. Now, two is the square root of four, three the square root of nine, and four the square root of sixteen. So here is the possibility of framing a mathematical law; and this illustration will prepare us for the law laid down by Fechner, arguing from the observations of Weber.

An Illustration of the Simple and Elegant Conclusion of the So-Called Law

If the eye can recognise the addition of an eleventh candle to the light of ten, how many candles would have to be added to a hundred before one could recognise that the light was stronger? A moment's reflection will make us all agree that to "spot" the addition of one more candle to ten, and to a hundred, are very different things. Weber and Fechner came to the simple and elegant conclusion that, if you need add only one candle to ten, you must add ten to a hundred, a hundred to a thousand, and so on. At any level of intensity of any sensation, a higher intensity of sensation can be felt when a certain fixed proportion of the original stimulus is added to it—say, one-tenth must always be added for candles; so that if one could appreciate the difference between a thousand candles and eleven hundred, one could appreciate the difference between one candle and a candle and a tenth.

Hence, according to Fechner's calculations, we have what he called "the fundamental law of psycho-physics," and what we now call the "Weber-Fechner law," which states that "the intensity of a sensation increases in arithmetical progression as the strength of the stimulus increases in geometrical progression," or—in language which the mathematical reader will prefer—"the intensity of a sensation increases as the logarithm of the stimulus."

The Absolute Sterility of a Law Hailed with Great Expectation

This discovery aroused the greatest hopes in the minds of many. Here, it seemed, was something on which we could build a science of the mind, a psycho-physics, just as astronomy could build up a new science on the law of gravitation. But decades have passed, far more observations have been made, and all the boastings of the materialists have been dissipated. "Psycho-physics" is already dead, just as its younger brother, "biometry," is moribund. The

"Weber-Fechner law," unlike the law of gravitation, has proved itself absolutely sterile. Nothing has come out of it. From Newton's law it was possible to predict and discover Neptune. No Neptunes of the mind, no least discovery, no illumination of any fact of the mind, has been derived, in all these years, from the Weber-Fechner law.

Why the So-Called Law for Measuring Mind Can Never Be True

The explanation is very simple. The law is not true. What the law asserts is, very roughly, true for certain sensations, under certain conditions, in certain people, sometimes, within narrow limits. It is always quite untrue for sensations of very low or very high intensity. It is ridiculously falsified by practice, as when a musician or piano-tuner learns to know when a note is only very slightly out of tune. Every violinist, in the course of his education, has made a fool of the Weber-Fechner law. Now ask what bearing practice, experience, attention, a night's rest, a good meal, starvation, a dose of strychnine, a dose of caffeine, a dose of alcohol, have upon the working of the law of gravitation, and instantly we see that we have been talking nonsense. We have been comparing incomparable things. There can be no such thing as psychophysics, for the sufficient reason that physics is physics and mind is mind.

Even Haeckel, fifteen years and more ago, was compelled, much against his will, to acknowledge that "modern psychophysics has fallen far short of the great hopes with which it was greeted twenty years ago." And if that had to be said of it, and by Haeckel, at the end of the nineteenth century, we need only add today that this supposed law has already gone to its own place with the rest of the puerile travesty of philosophy which men call nineteenth century materialism, and look back upon today with astonishment and "incredulous disdain."

The Mistake of Supposing that Mind Can Ever be Measured or Weighed

Of course, exact methods must be employed as far as possible in the study of mind, and, of course, we must duly value such results as those which are so extravagantly valued in the Weber-Fechner law. Only we must never suppose our measurements of the physical, and therefore measurable, machinery to be measurements of mind, which, *by its nature*, cannot be weighed or measured. The Weber-Fechner "law," in so far as it is true, and the similar "laws" of "biometry," in so far as they are true, are one and all the laws of the matter which is associated with mind, or the matter which is associated with life—which is really the same thing. The Weber-Fechner law expresses certain occasional facts of the molecules that make up nerve-fibres and nerve-cells—in other words, it is a physical law; but as it happens to relate to physical things which are the instruments of the psychical, it has been thought to be a law of the psychical. That is the confusion lying at the root of psycho-physics—a term which we now perceive to be pure nonsense, for it means the physics of the not-physical, an idea compared with which the threeness of two, the blackness of white, the squareness of a circle, the upness of down, are reasonable and obvious. Let us have done with this *ultimate* contradiction in terms—as if anything of sense or knowledge or wisdom could be erected thereon.

Points of Touch Between Simple Sensation and Creative Thought Found Everywhere

We return, then, to what we have agreed to be the unit of mind, *so to say*, and that is a simple sensation. The problem now is to bridge the interval between the simplest form of sensation and conscious, creative thought. If our ideas are to be clear and useful, we must compare man with other forms of life, which will show us mind in simpler forms, though it is to be remembered that the greater includes the less, and that the simplest imaginable manifestations of mind may be observed even in a Shakespeare at his desk, if he will but so much as run his pen into his finger.

In this comparative inquiry the psychology of our day has been immensely helped by the new biology, which is travelling ever further and faster from the mechanical lines to which it seemed to be bound at the end of the nineteenth century. The study of life has indeed come more than half way to meet the study of mind. A few years ago the comparative psychologist had a hard fight for it when he sought to gain acknowledgment for the existence of mind far down in the scale of living things. He was thought to be fanciful and paradoxical, and using his imagination unduly; but now, lo and behold, the biologists have continued their researches, and they have found signs of mind low down in the scale on their own account! And, finally, the greatest philosopher of our time has begun to convince his generation that the splendidly

sufficient reason why signs of mind are found everywhere in the regions of life is that life itself is really psychical.

It is now beyond dispute that sensation is to be found apart from the brain of the vertebrate; that it is to be found in the insects, in the amœba, in plants, in microbes even. It is also beyond dispute that, as we have said, the greater includes the less: and in man are to be found not only the manifestations of mind which are unique in him, but also those displayed in all the stages below him. Anyone may prove this for himself, if he has the apparatus, by pricking his finger and observing the behaviour of the white cells in a drop of his own blood, seen on the warmed stage of a microscope. He will there see living, sensitive, independent entities, which were part of his own person a few minutes before; and when he remembers that a large proportion of the total substance of his body —say, about one thirteenth—consists of his blood, which is crammed throughout with just such living, sensitive cells as he sees now under his eyes, he will be bound to realise that the greater does include the less, and even to ask himself what part of the sum of his *psychical* life may not, must not, be contributed by the psychical facts, the billions of sensibilities, of his white blood-cells *alone*, to name none other.

The Truth of Haeckel's Theory of the Cell-Soul and the Immanence of Mind

Here, beyond a doubt, the advance of knowledge entirely confirms the essential truth of the idea which Haeckel expresses by the term "the cell-soul." He is assuredly right in his assertion, though we may marvel at the conclusion which he draws from it, for to us nothing can seem clearer today than that to recognise the psychical in every living cell, and to admit that every cell has a psychical aspect—or "soul"—is to lead us not towards the denial and dethronement of Mind, but to the recognition of it as the essential part of all living processes. There, of course, is the crucial problem of interpretation; and we have to decide whether the psychical aspect, now admitted to exist in every living cell of a man's body, is only an epi-phenomenon, as Huxley asserted the consciousness associated with the brain itself to be; or whether, indeed, the psychical bodily material of body-cells and brain-cells alike is not the phenomenon or appearance, while Mind is the reality which is there embodied, incarnate. The reader knows the answer which modern philosophy returns to this question.

But now observe the consequences for human psychology of our discovery that the lowest forms of life have a psychology, and therefore that all the countless cells of a man's body are contributory to his mind, not one whit less than to his body. If, in Haeckel's bold language, every cell has a soul, psychology will merely confound itself if it ignores the fact, and proceeds on the assumption that the brain is the *only* organ of the mind. Undoubtedly the brain is *the* organ—that is, the organ *par excellence*—of the mind, nor will its pre-eminence ever be challenged. It is universally accepted. But we have challenged the notion that the brain is the *only* organ of the mind.

The Psychology of the Amazing Colony of Cells in a Human Being

That notion really denies the psychical aspect of all the living cells of the body except those of the brain; and we have seen that this psychical aspect can no longer be denied; it is asserted strenuously alike by Haeckel at one extreme, who believes that life and mind are reducible to matter and energy, and by Bergson at the other, who believes that matter and energy are the creatures and instruments of life and mind. Since, therefore, the psychical aspect of every living cell is now an undisputed fact—whatever disputes exist about its interpretation—clearly there is no room for dispute over the necessary inference that *human psychology must henceforth include and reckon with all the little psychologies of the amazing colony of cells that live together in the form called the human body.*

The steady advance of psychology to the position we have thus reached, from the position of, say, Huxley, that the mind is an accidental by-product of the working of the brain, is briefly epitomised in the last great chapter of Herbert Spencer—the "Reflections" that close his Autobiography.

The Triumph of Herbert Spencer's Theory that Thought is Everywhere

This memorable chapter begins with an examination of the assumption that the mind and the brain correspond, and Spencer has no difficulty in showing that that characteristic view of nineteenth century materialism is untrue, and that, on the contrary, "mind is as deep as the viscera." But once we have granted that mind extends beyond the brain—to, for instance, the liver and stomach, which means to the cells of which those viscera are composed—we have no choice but to go on to the logical end. Hence we find Spencer, at the end of his chapter, writing the notable sentence, never

too frequently to be quoted: "No less inscrutable is this complex consciousness which has slowly evolved out of infantine vacuity—consciousness which, in other shapes, is manifested by animate beings at large—consciousness which, during the development of every creature, makes its appearance out of what seems unconscious matter, suggesting the thought that consciousness in some rudimentary form is omnipresent."

The Truth that Body is a Symbol and Mind is What it Symbolises

It is but one, necessary, step from this last clause to the final truth that the body is a symbol, and Mind is what it symbolises.

The champion of the body will protest; but the protest dies on his lips when we have completed our statement by saying that the body, *therefore*, is far more important than its most materialistic champions had thought it, and that we must study it with new insight, new care, new respect, new solemnity, because of the almost awful, palpable reality with which modern science applies to the body, and to all the body, the words against which science falsely so-called has long blasphemed—" Ye are the Temple of the Holy Ghost."

From a very different field of thought and inquiry we are now gaining confirmation of the view that, so to say, the body, the whole body, is the physical complement of the mind—the view that the whole body, and not merely the portion of it called the brain, is, as it were, the visible, physical " double " of what used to be called the soul. The field we refer to is that of insanity and mental disease. The study of the abnormal mind during the last generation has not merely been valuable in the treatment of it, but has thrown strange new light upon the normal—upon the real nature of man. And the argument here presented is that the trend of knowledge in psychiatry, the science of mental disease, is precisely parallel to the progress made by normal psychology.

The Backwardness of British Science in the Study of the Mind

Here, also, beginning with the brain alone, men have been compelled to extend their inquiries until, by most unexpected and astonishing paths, they discover that the *whole* of the body, and not the brain only, is the organ of the mind. If every cell has a " soul," what else can we expect than that the health and disease of the mind are the counterparts of the health and disease *not* of the brain only, but of every cell of the body as a whole?

That is precisely the conclusion of modern psychiatry. Unfortunately, in this country we are far behind in our study of this subject. The pioneer in the humane treatment of the insane was the immortal Frenchman Pinel; and it is today in France, Switzerland, and Germany that are to be found the great leaders in this study of the mind in its aberrations, which throw such wonderful light upon the mind in its health. Here we are still in that state of darkness in which the study of hypnotism is supposed to be inseparable from charlatanry, and in which no medical student is required to study psychology. But when we turn to the great Continental students and thinkers, we find their researches into the mental manifestations of what we roughly call insanity, in all its forms, leading them to the conclusion that the whole of the physical must be reckoned with if we are to understand the whole of the psychical.

The real truth is that long ago expressed in the ancient motto, " Mens sana in corpore sano "—the sound mind in the sound body; not the sound mind in the sound brain merely. For we discover that the entirely sound brain cannot exist except in an essentially sound body.

Mental Phenomena not Entirely Dependent on the Brain which Displays their Symptoms

It is worth while to indicate the chief argument of the modern school, which insists upon the importance of the whole body in relation to the whole mind. For the full measure of the arguments we should require to survey the great Continental volumes on abnormal and morbid psychology, but the chief fact which they all express can be briefly and clearly stated. It is that we find morbid states of mind associated with brains that are healthy in structure; and that, when thus driven beyond the brain and its structure for the key to the mental phenomena, we find that key elsewhere in the patient's body. The symptoms are displayed by the brain, and we blame the brain, but that is our unwisdom merely. The brain is an organ, and an organ requires conditions. Thus one may try to play a musician's " organ " in a vacuum, and no sound will issue. If we therefore blame the organ itself, so much the worse for us.

Just similarly the essential organ of mind, which we call the brain, is only part of a greater whole. It needs the brain and the rest of the body to display the music we call Mind, as it needs a pipe-organ and the atmosphere around it to embody the music

of sound. This analogy of ours is not far-fetched. All of the characteristic and familiar mental phenomena of anæmia are due simply to the inadequate supply of air to the organ of the mind, owing to the fact that the red cells of the blood are too few in number and too poor in hæmoglobin to keep the brain sufficiently well aerated. It is impossible to work such a brain at the intensity which a better supply of air makes possible. Just so the organist cannot play a long fortissimo passage if the organ-blower is having a holiday, and only his ten-year-old boy is available for his task. The boy cannot supply air enough; nor can the pale blood of an anæmic girl whose mental organ we are trying to drive at the intensity possible for a healthy, red-blooded person, whose brain is richly supplied with air.

That is merely one illustration, though perhaps a sufficiently striking one, of the truth that modern psychology must reckon not only with the essential organ of mind, which we call the brain, but also with all its accessories, which are indeed no less essential, though less obviously so.

The Soul in us that Comes from One Original Birth-Cell

In future chapters this leading principle of psychology will become evident—as when we discuss the internal and organic sensations of the body, the facts of subconsciousness, dreams, and the various forms of the "hypnotic state" so called. The present necessary purpose will be served if the reader is fully prepared to accept the idea that the whole body, and the whole of the bodily functions, as we call them, must henceforth be reckoned with as having their psychical side and psychical significance; and let not the hitherto convinced materialist protest that he will follow us no further for has not his own champion taught him, these many years past, that every cell has a soul?

The full measure of this theory of the body, and the attitude which modern psychology must assume towards it, is yet to be realised. It is involved in consideration of the fact that, if the body and brain of Shakespeare were developed from a single microscopic cell, which was the young Shakespeare, so also the mind of Shakespeare must have been developed from the "soul" *of that cell.* This is the almost inconceivable fact which was referred to in the quotation from Herbert Spencer, where he spoke of "consciousness which, during the development of every creature, makes its appearance out of what seems unconscious matter." Plainly the stress-word in that sentence is *seems;* plainly we have no choice but to acknowledge, in the first cell from which any and every one of us is evolved, as much to come of *psyche* as of body. But what a truth to take the breath away this is!

The Parallelism of Mind and Body at Every Stage of Development

It needs no demonstration nor argument, once fairly stated; and it is evidently the logical antecedent of the principle upon which we have been trying to insist—that the whole of the developed body must be reckoned with in the study of the whole of the developed *psyche.* Plainly, mind and body are parallel at all stages. We can make no exceptions. Observe now what men were compelled to argue in the past, in that thick night which intervened between the day of antique learning and the dawn of science in our own day, beginning at the Renaissance.

How to account for the "soul" was the problem, and it had to be answered in terms which should be sufficiently degrading and insolent to the body. The reply of Jesuit speculation was that the soul is inserted into the body of each child *at the moment of birth.* Though this absurdity once stood for the best of human wisdom, it may very briefly be dismissed today, when we have traced the stages of human development which precede birth, and when we know that birth is simply a change of environment, and that each one of us has been alive for many months before birth. We have only to consider cases of premature birth and so forth to realise that the Jesuit theory is too hollow to explode—there is nothing in it.

All Powers and Tastes and Qualities Born from the Cell

Plainly, the psychical "counterpart," "double," "aspect," or being of man, whatever we are to call it, has the same relation to the body and brain of an infant five minutes before its birth or five minutes after. The absolute necessity of logic drives us backwards, from the adult to the child, the child to the infant, the infant to the fœtus, the fœtus to the embryo, back at length to the single cell, a physical and psychical being, which is none other than the youngest state of the physical and psychical being we call man. Nay, more, though the mind almost reels at the journey. "At length," we said, but even this beginning had its beginners; and the self-control, the love of flowers or music, the bad

temper of any one of us, may have passed to us from either of our parents as a psychical counterpart of the tiny germ-cell which we know to be represented by and in one half of each of our own billions of body-cells today, and the "soul" of which is no less in our "soul." Such are the plain, everyday, ordinary facts which anyone can observe for himself in an hour with a microscope, a museum, and any ordinary family of human beings to look at.

Miracle and Mystery Enough to Stagger Sextillions of Infidels

And, on the controversy regarding "miracles," we begin to realise what Pasteur meant when he said "Tout est miracle," or Walt Whitman when he said that "A mouse is miracle enough to stagger sextillions of infidels." Indeed it is; for in all that we have been saying, the word "mouse" might be substituted for "man" throughout, and practically not a comma need be changed. Whether in mouse or man, or in any other such creature, the persistence of mental organisation, in parallel with the physical organisation, through the germ-cells from generation to generation, is indeed mystery enough "to stagger sextillions of infidels."

The consideration of man from his earliest stage, as a single cell, to maturity, has now taught us clearly that his mind must be "co-extensive"—if for a moment we may regard mind as having extension—with the *whole* of his body, whether and when that is a single cell or the adult body we know so well. This is clearly the only possible inference to draw from our modern knowledge of the development of the individual body.

The Whole Body Conceived in Psychical No Less than Physical Terms

Here we have specially insisted upon this argument, because it is usually put in the background, while attention is specially directed to the parallel and analogous argument drawn from the whole history of the human species. In this, as in all other cases, we see the great principle of Von Baer—that the history of the individual is a sort of recapitulation of the history of the race. And so the argument that man's physical body and life are complementary to and parallel with his psychical being—and that the whole body must be conceived in psychical terms, no less than in physical—is equally valid, whether we trace the history of any man from his first condition as a single cell onwards, or whether we trace the history of mankind at large from such early forms of life as the pond-amœbæ, of which he contains the most amazing likenesses by the million in his own blood.

Thus, to extend slightly an illustration employed by the writer many years ago, we may contemplate three objects in a row before us, (1) a man, (2) a white cell from that man's own blood, seen under the microscope, and (3) an ordinary amœba, seen under a second microscope. Now apply some disagreeable stimulus, such as a tiny drop of some irritant acid, to all three in turn. They withdraw; they exhibit conduct of a definite kind. Towards other stimuli they will move, exhibiting conduct of another kind. Chloroform, alcohol, and so on will affect all three in similar ways, soon producing lack of response, abolishing irritability, anæsthetising, if we may not say "abolishing," consciousness in man, man's leucocyte, and amœba alike.

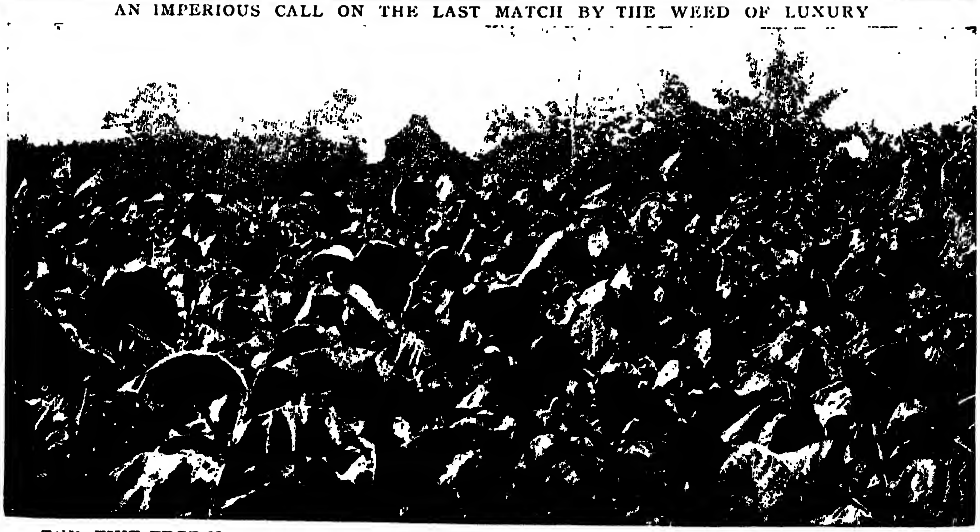
Body and Mind Co-Equal, Co-Extensive, Correlated, Utterly One

Having thus examined extreme instances side by side under similar conditions, and having first prepared ourselves by recognising that mind in its unitary simplicity is the power to feel, is *sensibility*, our simple observation teaches us once and for all that, whether we compare a man with one of his own tiny cells, or both with the humblest form of animal life we know (and any vegetable organism might have been added for completeness' sake), bodily life and mind are co-equal, co-extensive, correlated, of common origin, parallel, more utterly one, indeed, than words can say. The argument from evolution, the argument from embryology, the argument from psychiatry, the argument from comparative psychology, the argument from heredity—one and all lead us to the same conclusion.

And that is why we did well to use for our beginning the recognition of sensation, the power to feel, as the simplest mode of mind. Once that was granted, we found that mind was co-extensive with life—which is not only truth for the philosopher, but has a practical value for the student of man, meaning as it does that the study of man's psychology requires and employs the study of his physiology in every aspect. Nowhere is this fact better illustrated than in the physiology and psychology of the queen of the senses, which is vision; and to the study of the eye and of visual sensation we are now prepared to proceed. We shall find that the study of the eye is full of light for what shall follow.

THE PLANT THAT GIVES MAN A NEW WANT

AN IMPERIOUS CALL ON THE LAST MATCH BY THE WEED OF LUXURY



THE FIVE-FEET-HIGH TOBACCO PLANT OF THE EAST INDIES, READY FOR CUTTING

TRUTH ABOUT TOBACCO

Things Taken into the Body that it Does Not Need, but Tries, Sometimes Unsuccessfully, to Endure

THE UNDOUBTED EVILS OF DRUGS

ONCE we have begun to discuss drugs and their effects, we discover that the subject is easier begun than left, for it involves a good deal more than the doctor's prescription or the morphinomaniac's needle. Nor must familiarity deceive us as to the character of drugs which, perhaps, we had never thought of as such, yet as to which there is no room for doubt, quibble, or argument of any kind; say, for instance, the alkaloid caffeine, found in tea and coffee, or the theobromine found in cocoa. Further, we are not to be deceived by such facts as that the drug in question produces no ill-effects, or none that we can detect; or that it is habitually taken by healthy and sensible people--such as ourselves; or that the drug is not swallowed, or not chiefly swallowed, but is merely inhaled or absorbed from the nose, like the nicotine and other drugs contained in tobacco. We need only remind ourselves that the most effective way of administering chloroform is by the nose and lungs. Yet the fact is that very few people, outside the ranks of professional students, such as doctors and chemists, are prepared to talk or think honestly on this subject. Like nearly all of us, in one direction or another, they will do the thing, but they dislike its name. The smoker has a drug-habit, and so has anyone who habitually takes alcohol or tea. This does not mean that tobacco, alcohol, and tea are either better or worse than they were before, but it simply means that we have named things properly—which is the first step to understanding them. And now we can proceed to examine the action, the uses, if such there be, the abuses, if such there may be, of these various drugs, and the appropriate treatment of any ill consequences.

We are to be fair-minded, even when we have called a spade a spade and a drug a drug, no less than—indeed, more than—when we preferred to use the name "drug" only for what our neighbour uses and we refuse. The simple truth is that there are drugs and drugs, and there are cases where the exact definition is almost impossible. But we need not be tied down to any definition, more especially as the old ideas about foods are breaking down, and we learn that substances may be useful in the diet, or essential, though they do not "form tissue or produce energy." When we supposed that nothing was a food that did not do one or both of those things, we could confidently call everything else a drug, but we see that this simple mode of judgment is too simple, for a normal diet, as we shall learn in due course, contains numerous chemical substances which neither form tissue nor produce energy, but which we should die without. Indeed, common salt, a necessary ingredient of our diet, neither forms tissue nor produces energy; it is, so to say, a normal drug, an essential chemical for the working of the body.

That admission we must grant for common salt, and for several other substances—the proof being in the eating, or lack of eating. Without them we die, or are very ill. But the case is quite different with the drugs which are now to be discussed. Common salt is found in normal, natural articles of diet, such as wheat and flesh; and if any advocate of some food theory questions that one or both of these are normal, we need only refer to the one food-substance that owes its existence to the purpose of being consumed, which is milk. Milk contains common salt. The tissues of the body also contain common salt. Let it be shown, of any substance, that it is found in normal milk and in the normal body, and it is beyond criticism. Let it be shown, of any substance, that it is *not* found in milk (the

complete and perfect food for, at any rate, the most important stages of development), and that it is not found in the normal body, except perhaps as a waste-product, and the substance in question is, on those two grounds, open to criticism, and demands it.

Let the reader duly observe, then, that we have substituted a genuine, natural, scientific criterion for such absurd and thoughtless ones as are usually allowed to suffice. The question is not whether, say, caffeine or nicotine does no harm, or does one good, or is used by everybody; all these assertions may be true, but the substance is no less *outside the physiological pale* if we find that it does not occur in the only food made to be a food; and that the normal body does not contain it. We have only to think of the constituents of milk, its albumin, fat, sugar, salts, water, and to compare them with the composition of the body, which consists of just the same things, in order to see how real and deep is the line here drawn, the line which we call the physiological pale, and outside of which are, for instance, the alkaloids found in such plants as provide us with tea, coffee, cocoa, and tobacco - to say nothing as yet of that product of the decomposition of sugar by the yeast-fungus which we call alcohol.

The Difficulty of Excluding the Idea of Bias when Discussing Tobacco

Everyone who has had an elementary course in chemistry knows at once that nicotine can only be classed with atropine, found in belladonna; that caffeine can only be classed with morphine, and alcohol with ether, which is a chemical modification of it. These things may be good, bad, and indifferent, which is what we have to determine, but at least let us know where we are when we discuss them. We are among substances which do not exist in normal food, and are not constituents of normal protoplasm. Even in the plants which produce them, they are not parts of the living substance, but are products of excretion.

We may begin with tobacco, which is a subject of greatly increased importance during recent years, owing to its considerable use among women as well as men. The man of science has the utmost difficulty in persuading people that he writes impartially on this or any subject which comes so close to the likes and dislikes of his readers. Those who like what he says will applaud, and those who dislike it will dismiss him as biassed. The present writer can only assert his earnest desire to state only the truth so far as he knows it, without fear or favour. He smoked freely and regularly for many years, at work and play, without any certain symptoms of injury, but he has not smoked for three years, and will never smoke again. The reader must make what allowance for bias, in either direction, he thinks fit—if any; but the writer's public and published teaching on this subject was exactly the same when he smoked as now.

Smoking the Least Harmful Form in which Tobacco is Used

Tobacco may be either smoked or chewed, and the action of its contents is essentially the same in the two cases, only that chewing is much more likely to be practised to obvious excess, owing to the action of combustion upon tobacco when it is smoked. But we must be quite clear that, notwithstanding popular statements often made, the essential constituents of tobacco are absorbed by the smoker as well as by the chewer. This we shall see when we have first defined the composition of tobacco. To do so completely would require a treatise, for the chemistry of the tobacco leaf is extremely complicated, and it varies in considerable degree with different kinds of tobacco, and according to the particular microbes which have been at work in the process of curing it. For our purpose it suffices that tobacco in general contains a proportion of nicotine, and a number of other substances, less potent, but far from inert. Some of these substances, if isolated from the leaf, and used even in quite small quantities, are found to be surprisingly powerful. But the quantity of nicotine and the other active principles in ordinary tobacco is, of course, very small, or smoking, to say nothing of actual chewing, would be quite out of the question.

Nicotine, Weight for Weight, Slightly More Poisonous than Prussic Acid

One-third of a grain of nicotine has killed a man; and if we compare this drug with prussic acid, weight for weight, nicotine is slightly more poisonous; indeed, chemistry knows only very few poisons more powerful. It follows, obviously, that the quantity of the drug which enters the blood when tobacco is smoked or chewed must be exceedingly small—though anyone who remembers his first experiences in smoking will realise that even those small quantities may create more disturbance than can be accounted for by the room they occupy.

The question arises, however, whether there is any nicotine in tobacco-smoke; and

at one time it looked as if there could not be, for nicotine is combustible, and during the process of smoking tobacco much of the nicotine is certainly burnt up and destroyed, being reduced to mere carbonic acid and water and innocent nitrogen. Certainly all the nicotine that still remains in the portion of tobacco that is being burnt at any given moment is consumed. Probably, also, the heat of the combustion is sufficient to oxidise and destroy all, or nearly all, of the nicotine in the tobacco that is just about to be burnt, and is so near to the site of combustion as to be very hot; hence the clause "that still remains," when we spoke of the tobacco actually burning, for in that probably very little nicotine is present to be burnt.

Does the Volatility of Nicotine Reduce to Insignificance the Amount Absorbed?

But the great characteristic of nicotine is its volatility. When it is warmed it becomes a vapour or gas—a most exceptional characteristic for an alkaloid, and one which sharply distinguishes nicotine from nearly all familiar alkaloids such as morphine and strychnine. Hence, as one draws in a mouthful of smoke, one draws in with it a certain amount of nicotine in gaseous form, derived from some part of the tobacco between the lips and the part undergoing combustion. No doubt the proportion is tiny, but the substance is potent.

If the smoke puffed out by the smoker be examined for nicotine and other constituents, we find very scant traces of any of its volatile constituents, for these have been to a great extent absorbed, and it is this absorption that matters everything, and must be carefully defined. It has often been asserted, outside the ranks of competent students, that smoking really owes its attraction to the sight of the smoke, and that thus blind men do not smoke. Inquiry among the blind contradicts this assertion; they include a smaller proportion of smokers, but there are many blind smokers notwithstanding.

The Interest of the Smoker Dependent on the Absorption of the Poison

It is true that mere taste is an element, though a subordinate one, in smoking, and that seeing people can scarcely taste in the dark. But when one has become accustomed to the dark, as the blind man does, the sense of taste learns to do without the accessory stimulation of the nerves of sight. The blind man eating his dinner enjoys it as we do, and very much more than we should if we had to eat it in the dark, as he does. Hence the blind man is not deprived of the taste-element in smoking. But even if he were, smoking is still welcome to him, as it is to those whose sense of smell has been atrophied from one cause or another. There is no need whatever to try to invent novel and fantastic reasons for smoking; the real reason is beyond dispute, and is simply the effect produced by the absorption into the blood of nicotine and certain other constituents of tobacco-smoke.

If there were no such absorption, smoking would be of no interest to the hygienist, except for its possible effect upon the mouth, tongue, and lips; and, indeed, it would be of no interest to the smoker. Just as we live not by what we eat, but by what we assimilate, so the effects of nicotine depend not upon its entrance into the mouth, but upon the amount of it that actually circulates in the blood and reaches the nervous system. The amount entering the blood varies in different people, according to the mode of smoking, and so forth; and the proportion existing in the blood at any given moment probably varies according to the idiosyncrasy of the smoker, and the rate at which his tissues and blood burn up the poison—just as is doubtless the case with morphine and alcohol.

The Amount Absorbed Measured by the Absorbing Surface Exposed to the Nicotine

But, other things being equal, the amount of nicotine entering the blood must depend upon the area of absorbing surface which is exposed to the smoke. Necessarily very much less nicotine is absorbed from the mouth only than when the smoke is exhaled through the nose, and past its large and delicate mucous membrane, which is richly supplied with blood-vessels, and has considerable powers of absorption, as the snuff-taker demonstrates. Further, the surface of the nose has valuable functions of its own to discharge, and is very liable to injury and degeneration of various kinds, especially in city dwellers, who habitually breathe dirty air. On these grounds the smoker may be advised to avoid the habit of exhaling the smoke through the nostrils—though the satisfaction of doing so, and offering a larger absorbent surface to the smoke, is quite intelligible.

But if that practice is somewhat to be frowned upon, far more serious words are required when we come to deal with the second method by which the smoker increases his area of absorption and so obtains a more intense action of his drug.

This is, of course, the practice of inhaling the smoke. The reader has only to consider his elementary anatomy in order to realise that, when the smoke is exhaled through the nose, it need not have been really inhaled at all, but merely allowed to pass into the nose from the back of the mouth, behind the soft palate, which the smoker drops for the purpose—instead of keeping it raised and shutting off the nose, as he does when he swallows. But the inhalation of the smoke is a different matter altogether. It means the passage of the smoke into the windpipe and bronchi, and the exposure of the delicate lining of these air-vessels to it, and thus the absorption of much more nicotine than the mouth and nose can possibly take up. That, of course, is the reason why the smoker inhales.

A Simple Test of the Amount of Deleterious Matter Absorbed from Tobacco

A simple index of the difference between ordinary smoking and inhalation may be furnished by passing the smoke from the lips through a handkerchief in the two cases respectively, and comparing the stains, when the smoker will find that a much slighter stain is produced by the smoke that has been inhaled, showing how much of its contents has been left in the lungs. This convincing test is only an index, however, of the absorption of nicotine. The brown mess on the handkerchief is not nicotine in either case, any more than the oily mess that accumulates in a pipe and is commonly called nicotine by smokers. Since much less than one drop of nicotine will kill a man, it is plain that the visible brown material in the pipe, or on the handkerchief in this test, can only contain an extremely minute proportion of nicotine, if any. Nevertheless, the handkerchief test remains; and there is every reason to suppose that the smoker is decidedly better without the brown material which the handkerchief intercepts when the smoke has not been inhaled, even though nicotine be not included among its many constituents.

Inhalation the Special and Serious Danger of Cigarette Smoking

Few smokers can ever learn to inhale the smoke of a cigar or a pipe—for a reason which we shall have to study soon. Therefore the inhaler smokes cigarettes, and the possibility of inhaling their smoke is thus the special danger of cigarettes. The habit is one of which few people can break themselves, and it is highly desirable that the young smoker should be warned against it. As long as one has never inhaled, smoking is just as enjoyable, and far safer, without it. Unfortunately, the youngster rarely lacks a supply of eager tutors, glad to teach him an undesirable habit, in this as in any number of other directions. This is one of the facts of human nature which are so common as to seem normal, and yet are evidently morbid, but there the fact is; and the best we can do here is simply to warn any young reader, in especial, that if he or she—as one must add nowadays—is encouraged to try the inhalation of cigarette-smoke, it is well to look to the end thereof before making the experiment.

Fortunately, many people cannot inhale even mild smoke, because of the resentment exhibited by the larynx. For let us remember that every atom of gas, dust, smoke, or anything else which enters the lungs must do so by the only route, which is through the tiny aperture between the two vocal cords in the larynx, or voice-box. The lining of the vocal cords is intensely sensitive, as it should be, for they are not only the reeds of the human pipe, but also the responsible doorkeepers of the lungs. Hence the first attempts at inhalation naturally excite coughing, and even the most seasoned inhaler of cigarette-smoke will cough if he accidentally inhales the smoke of a pipe.

The Tragedy of Spoilt Voices and Poisoned Tissues

In time, however, if the novice persists, he will find that he can inhale without coughing or serious discomfort, and lastly with pleasure—the converse of the pain which he feels when he is deprived of what he has induced himself to need. But this insensibility of the vocal cords and lining membrane of the larynx is not purchased for nothing. It means that the lining has become thicker and coarser, just as the skin of the hand or the heel responds to irritation, friction, or pressure; and if the lining of the vocal cords becomes thick and coarse (as even frequent and prolonged use in speech and singing need never make it), the result is that the voice becomes husky and loses its beauty and reliability.

In many cases this is a real tragedy. It is a pity whenever it occurs, but especially so when it occurs in those who have beautiful voices, and who often depend upon them for a livelihood. Doctors who have had opportunities, and, above all, doctors who specialise in the throat and larynx, know how constantly young singers lose their voices, spoil their careers, and drift into wretched courses because this vice of the inhalation of cigarette-smoke—

usually aided by alcohol—has taken hold of them. It *is* a vice; and an honest writer cannot suppress the word, for its consequences are vicious, and the essence of it is maltreatment of one of the most delicate, valuable, and irreplaceable parts of the body—the organ of the "living voice." Needless to say, when the doctor, whether general practitioner or laryngologist, is faced with his patient—a medical student, a young singer, a curate, even a girl in her first season—and when he discovers that the state of the voice, and the tendency to coughing and "hawking," are due to inhalation of tobacco-smoke, he has no rational or useful course but to say that the inhalation must cease. Lotions and gargles and medicines and change of air and rest of the voice may all be tried, but they will all certainly fail, and the trouble, even if relieved by vocal rest, will certainly recur, unless and until the cause is removed.

Nothing easier, anyone may say who has no idea what these drug habits mean. But no one will say so who has fairly faced the facts, for nicotine is a characteristic representative of what are called the neurotic poisons, because of its action on the nervous tissues; and we shall soon see that these poisons have an insidious method of establishing themselves, so that they can scarcely be distinguished from our natural needs, like air and food and water.

The Absolute Certainty of the Poisonous Character of the Nicotine Drug

The fact that tobacco is a poison is no more disputed by anyone now than the like fact regarding alcohol will be disputed by anyone twenty years hence. It is curious that the people who argue that alcohol cannot be a poison because so many people take it without apparent injury do not apply the argument to nicotine, which would show its absurdity. Nicotine is no less a poison because the adult is usually capable of acquiring a complete immunity, or what appears to be a complete immunity, to its action. Let him remember the bad quarters of an hour which his acquirement of immunity cost him. Let him remember also that the nervous paralysis produced by tobacco, when pushed, is extreme. It may lead to death, and would do so in any man or animal not protected by habit. Short of that, this action of tobacco used to be deliberately employed by surgeons, in the days before anæsthetics, in order, for instance, so to weaken the nervous system that the muscles around a dislocation might be relaxed, and the surgeon could then reduce it. We have kinder methods of reducing dislocations now, but this historical fact is worth citing.

The objection to the description of nicotine as a poison is naturally raised by the habitual smoker—the case being the same with alcohol, opium, cocaine, and all the other neurotic poisons which induce habits. The habitual smoker, as, for instance, the patient with a smoker's throat, when told to stop smoking, or at least to stop inhaling, replies that the tobacco, so far from being a poison, keeps him well. He tries to drop it for one day, and finds himself so nervous and shaky and miserable—in fact, so *poisoned*—that he is almost bound to start again in order to obtain relief. Thus smokers argue that smoking "steadies their nerves," increases their sense of well-being, and favours digestion; that the after-breakfast pipe is a useful and invaluable aperient, and so forth.

The Smoker's Pleasure the Satisfaction of an Artificially Acquired Morbid Craving

But the fact is that the satisfaction which the regular smoker obtains is precisely the same in essence as that obtained from his alcohol by the drinker, or from his morphia by the morphinomaniac. This is the satisfaction of an artificially acquired—if indeed we must not say a morbid—craving. The drug is in itself a poison, probably to all forms of life, just as alcohol and prussic acid are, though both of these are produced by living plants more or less directly. If close enough chemical inquiry were made, we should probably find that, as is known in the case of morphine, and as is doubtless true in the case of alcohol, the poison produces from itself secondary poisons which require a further dose of the original poison as an antidote to them. Thus a vicious circle is initiated, the details of which have been apparently fully worked out in the case of morphine, and it notoriously consorts with the general experience in the case of these various narcotics.

The First Dose of Tobacco the True Test of its Effects

Thus one may point out *seriatim* quite a number of beneficial results which are evidently obtained from smoking, but it has to be admitted that these good results are essentially in the nature of neutralising the secondary effects of previous smoking. The fair test, in all such cases, is to observe the results of the first dose of the substance in question upon a normal person. Foods and poisons of all kinds soon sort themselves when this simple test is applied.

Ask the youngster who has just limply dropped his first pipe whether smoking aids digestion and soothes the nerves; and if he is not in a position to answer you at the moment you can answer yourself.

We have undertaken in this section to consider the health not only of adults, but also of children. Here there is no room for doubt or quibble; and grown-up people may reflect at their leisure on the likelihood that any substance, essentially a poison to the young, can be essentially anything else when the young are a little older. As regards children, the adult is quite prepared to accept legislative proposals which cannot by any chance interfere with his own comfort; and thus, under the Children Act, smoking in public by children, and the sale of tobacco to children, are interfered with. There are no arguments whatever in favour of the use of tobacco in any form by children. The common statement that smoking by small boys "stunts their growth" may quite possibly be true, but there are no comparative observations on this point, so far as the writer is aware.

The Special Reasons Why Women, Especially Expectant Mothers, Should Not Smoke

As regards the use of tobacco by women, there is no reason to suppose that there is any essential difference between the two sexes in this respect, with one exception. That exception is the expectant mother, who, if she smokes, must undoubtedly be exposing the young tissues and the developing nervous system of her child to a deleterious influence. No exact observations exist on this subject, unfortunately; nor is anything known as to the possible excretion of any constituents of tobacco-smoke in the milk of the nursing mother.

Though the great majority of smokers appear to acquire complete immunity to their drug, and though nearly all soon reach a degree of dosage which they are not tempted to exceed, or which, at any rate, they can and do refrain from exceeding, yet definite disorders due to smoking are well known to medical science, quite apart from the more subtle and doubtful questions as to, for instance, the effect of prolonged smoking upon the walls of the arteries. In such directions as that we still need much more knowledge, for whatever action exists must certainly be slight; but as regards the heart and the eye the possible effects of over-smoking (whatever quantity that may exactly mean for the individual in question) are clear and characteristic, like the effect upon the throat. This latter, however, is more a question of local irritation by means of heat and irritant particles, but the action of tobacco upon the heart and eye is purely toxic.

Nicotine, as we have said, is a typical neurotic, or nervous, poison. The slight tremor of the extended fingers of the excessive smoker is an indication of this action. Closely allied to it is the symptom known as "tobacco-heart," with its irregular, hasty, unstable pulse, and attendant consequences. Here, no doubt, the action of the nicotine is not upon the muscle fibres of the heart, any more than it is upon the muscular tissue of the arm, when it produces finger-tremor; it is almost certainly upon the nerve-cells in the nerve-ganglia of the heart, which initiate its beat.

The Special Ailments of Tobacco-Heart and Tobacco-Blindness

"Tobacco-heart" is a very common result of inhalation of cigarette-smoke, and it also occurs not infrequently in those who chew tobacco. The problem for the doctor and for the patient in such cases is to remove the cause; but, as we have seen, that involves breaking a vicious circle, and mere injunctions and exhortations may not suffice. Even more serious, in some ways, is "tobacco-blindness," a very characteristic condition, in which the sensitiveness to light of certain parts of the retina is lost. This is most frequently met with in those who chew tobacco, and especially in workmen who have learnt the habit of chewing early in the morning before breakfast, for then the absorption of the constituents of the tobacco is made easier and quicker. The symptoms in the throat and larynx are often very obstinate, even when the cause is removed, for there the cause is acting in a different way, and is liable to produce structural changes in the parts affected.

The Possibilities of Cure for Those who Give Up the Use of the Drug

But "tobacco-heart" and "tobacco-blindness" are recovered from with great rapidity and completeness, almost invariably, if the tobacco be stopped. The reason is that here the disorder is, in the language of doctors, not organic, but functional—that is to say, the poison has not damaged any structure, so far as we can observe, but merely interferes with the function of the nervous structures, while it is present. If, then, the poison *and its secondary products* can be got rid of, the normal functions, whether of the nervous structures of the heart or of the eye, will be

restored, and that is what we usually find. It is a fortunate fact, and notably to be contrasted with the action of certain other neurotic drugs, like alcohol, which is also a local irritant wherever it is carried, and is thus liable to leave permanent changes behind it in some degree. But the problem of leaving off the tobacco remains; and only those who have not experienced this craving and the distress of refusing to gratify it will grudge a little space to its consideration.

The Need for Real Consideration for Those Who Seek to Give Up Smoking

As in the case of other drug habits, the smoker who is trying to break or reduce his habit requires real consideration. His habit may be in some cases a vice, and one which he deliberately began, but he is now in the grip of a vicious chemical circle, the first poison producing secondary poisons, which require a further dose of the first to neutralise them, and so on. It is found that tincture of *nux vomica,* prescribed by a doctor—for it contains the poison strychnine—may sometimes help the patient. The sucking of strong peppermints is widely reported to be useful in allaying the crave of the deprived smoker, and this is what we might expect from the known action of oil of peppermint upon the nervous system.

Most men can help themselves to keep down their smoking by making rules as to when they begin, or how much they will allow themselves, every day. "Lead us not into temptation" remains always psychologically true, and it is a good rule not to take tobacco about with one. In the breaking of this, as of other habits, it is probably easier to be thorough from the first, and to remember that a single backsliding will neutralise a great deal of previous courage and self-control. This rule does not apply to opium and morphine, however, as we shall see.

Serious Dangers to Which Smokers are Specially Exposed

The smoker may also change his tobacco for a lighter kind, if he smokes a strong tobacco. But sudden changes of one's tobacco, other than from strong to light, may be dangerous, as has been pointed out by Sir Lauder Brunton—dangerous even to the extent of fatal heart-failure in some cases. There are many other poisons in tobacco besides nicotine, and the nature and proportions vary in different kinds of tobacco, so that the smoker may have established immunity to one familiar kind of tobacco and not to another.

Smokers are markedly and notoriously more liable to cancer of the lower lip, mouth, and tongue than are non-smokers, this being in accordance with the general rule that chronic local irritation of any kind is liable to set up the cancerous process. The lower lip is attacked especially in those who smoke a very hot-stemmed pipe, such as a short clay, and these cases are probably rarer nowadays than they were. The tongue is very frequently affected, however, not nearly enough having yet been done in this country to warn the public as to the exciting causes of cancer, and the way in which to avoid them. This subject must, of course, be dealt with in detail later. But it can never be too soon to warn the smoker, above all as he approaches the later forties and onwards—though many cases occur before then—that he should take instant warning from the development of persistently irritated or whitened or thickened patches on any part of his tongue, whether the "smoker's patch" on the back of the tongue, or those which often occur near the point where the smoke from the pipe is habitually directed into the mouth.

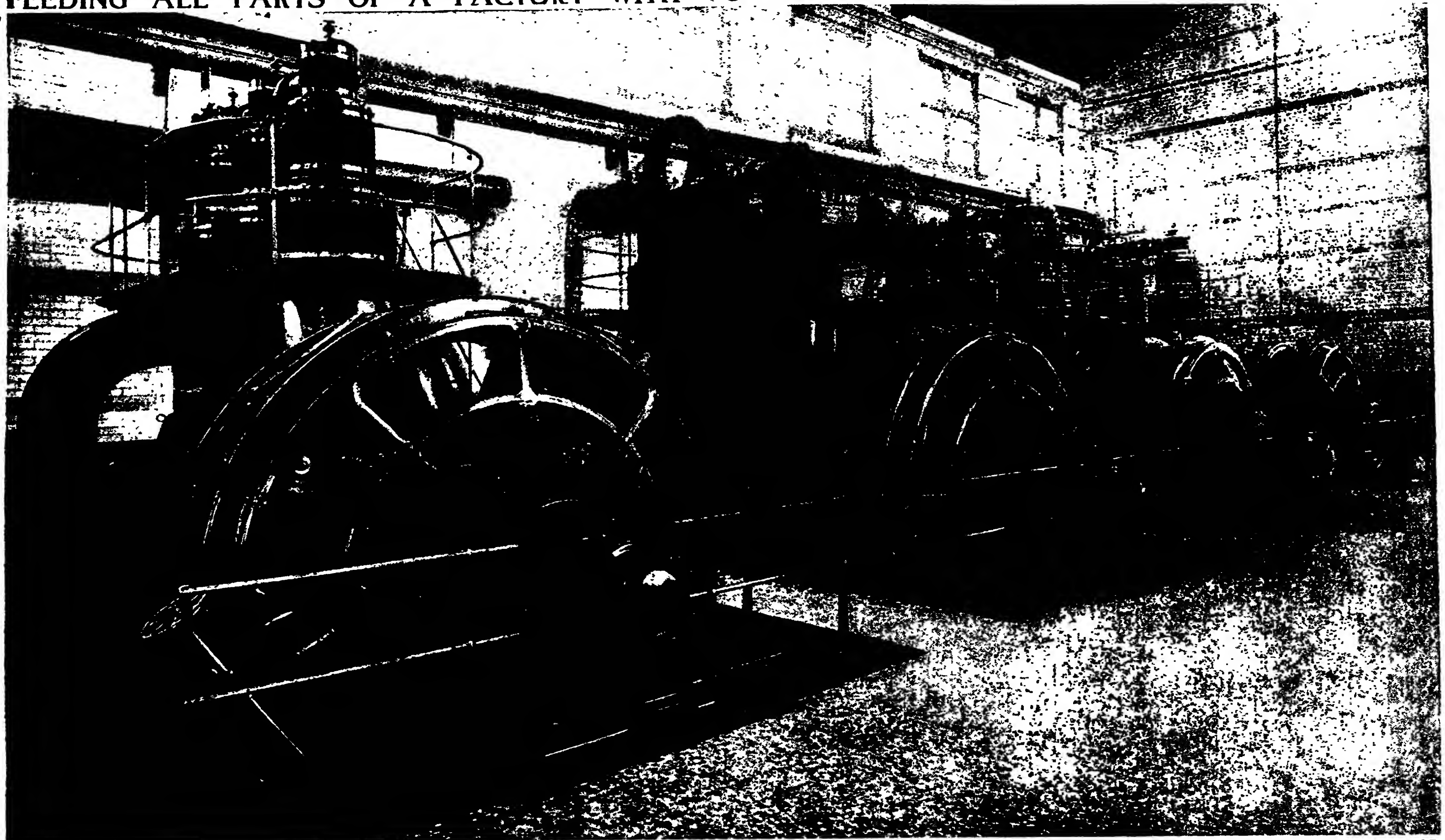
The Undoubted Increase of Liability to Cancer Through Smoking

Many fantastic explanations have been advanced in the past for the markedly higher incidence of cancer in these regions in men than in women, though women suffer far more from cancer elsewhere, but the reason is clearly evident to all modern students of cancer, They are unanimous on the subject. To this disease, also, if not most of all, the great rule of "prevention where preventable" must be applied; and so our last word to the reader, if he smokes, is that he *must* stop short of chronic, local irritation in any part of the lips, tongue, or lining of the mouth. This warning will save many lives, but few of the saved will know.

The man in whom the disease has appeared will do anything to save himself, will travel all over the Continent for help if he can, liberally reward all who help him or pretend to, and read everything that has been written on the subject. That same man would take no heed till his turn came, and would say "Thank you for nothing" when advice worth all the world was offered him.

Thus are we made. But occasionally opportunities offer—probably this is the first of such magnitude—which may enable the adviser, by a word or two, to save more lives from cancer than any hundred surgeons have ever done.

FEEDING ALL PARTS OF A FACTORY WITH POWER FROM A CENTRAL ELECTRICAL PLANT



AN ELECTRICAL INSTALLATION THAT DISTRIBUTES POWER BY SLENDER WIRES TO THE MACHINERY OF A MANUFACTURING FIRM WITHOUT NEED FOR SHAFTING AND BELTS

TRANSMISSION OF POWER

The Way in which Power, However Generated, may be Carried to Great Distances with Little Loss, and Split Up for Use

THE DIFFUSION OF WORKING ENERGY

The transmission of power is a wholly modern phase in a story of industrial growth. In the operation of the hand tools, alone used through untold thousands of years, the muscular power was applied directly to hammer, or chisel, or saw. The first transmission in mills marked a momentous advance. The windmill or the water-wheel harnessed Nature's forces, to be transferred thence to the spindles and stones a few yards away, by wooden shafting, wooden cog-wheels, and leather belts. When James Watt's epoch-making though crude steam-engines developed, the problem of transmission remained unchanged, still circumscribed by the mill walls. And thus matters stagnated right down to within the recollection of the present generation. Engines grew in size, and power, and efficiency. But still a big steam-engine supplied power to a mill or factory to be transmitted through shafts and pulleys and gears. Even an extensive modern factory was until very recently just a magnified mill. Many are today. The only difference is that the transmission takes place through longer shafts and belts, and more of them, and by more powerful drives. And if the mill or factory happens to be exceptionally large, then more than one engine is installed, simply to avoid having to carry shafts and belts to inconvenient distances. Lengths and areas are still, however, measured in yards—a few hundreds, more or less.

That briefly defines the system which held an apparently unassailable, and as yet unmenaced, position less than a quarter of a century ago, and which, where vested interests are involved, is, and will be, retained in service for many a year to come. Where vast sums have been sunk in plant and machines, the old system must be retained in hundreds of mills and factories. But what a tremendous advance is made when the machinery of a factory can be driven, and the place can also be illuminated, by power generated at distances measured by many miles! That is a realisation, an accomplished fact, beyond the wildest dreams indulged in when men now mature were young.

Transmission of power has therefore now two broad aspects, one being that where it is carried over long distances, the other over small areas. The first is the one which appeals more powerfully to the imagination, yet the second is of equal importance. The first concerns the supply of power to a mill or a factory or a town, or to groups of either. The second deals only with its distribution throughout a local area.

The great objection to the shaft, pulley, and belt system of driving is the enormous proportion of power lost in friction. In the best-equipped engineers' factories it is estimated that, for every horse-power given out by the engine, less than half a horse-power is available at the machines, one half, or more than half, being lost on its way in the rubbing of shaft journals, in the clinging of belts, and the sliding of the teeth of toothed gears. And if these mechanisms are badly fitted, the losses will be 10 or 15 per cent. greater. Even in a cotton-mill, which ranks highest in factory efficiency, the losses, though not so great, are serious. In one case it was found that a loss of 39 per cent. was going on—an engine giving out 1252 horse-power to do 896 horse-power of work. If an all-electric drive is adopted for distribution instead of shafting, pulleys, and belts, the loss is not nearly so great, being only about 10 per cent. of the energy produced.

Let us glance at the sources of power which are commonly harnessed into service, and consider them from the point of view of their value as agents for transmission.

These are steam, gas, oil, water-pressure, air, and electricity. Around each of these systems, problems diverse and difficult muster. For the methods of transmission are vitally related to the sources of power available, so that one must be considered with the other.

Steam—a mighty storage of energy that has formed an exhaustless theme for so many pens in the past—is being rudely shouldered out of spheres where formerly it was unchallenged. The reason is that you cannot transmit steam more than a few hundred feet in pipes without the loss of much of its energy by the dissipation of its heat. Therefore, the steam generator—the boiler—must be near the engine, and the power given out by the latter must be transmitted by other agents. These agents until recently comprised only the shafting and pulleys, connected by leather belting, or by cotton ropes (the alternative to belts used chiefly in spinning-mills), or by toothed wheels. By means of relays of these agents a very large factory can be served from one big set of engines, but with a sacrifice of, roughly, one half the power of the engine, lost in the friction of the transmitting elements. That has never been considered satisfactory, but nothing better was practicable until quite recent developments in electricity.

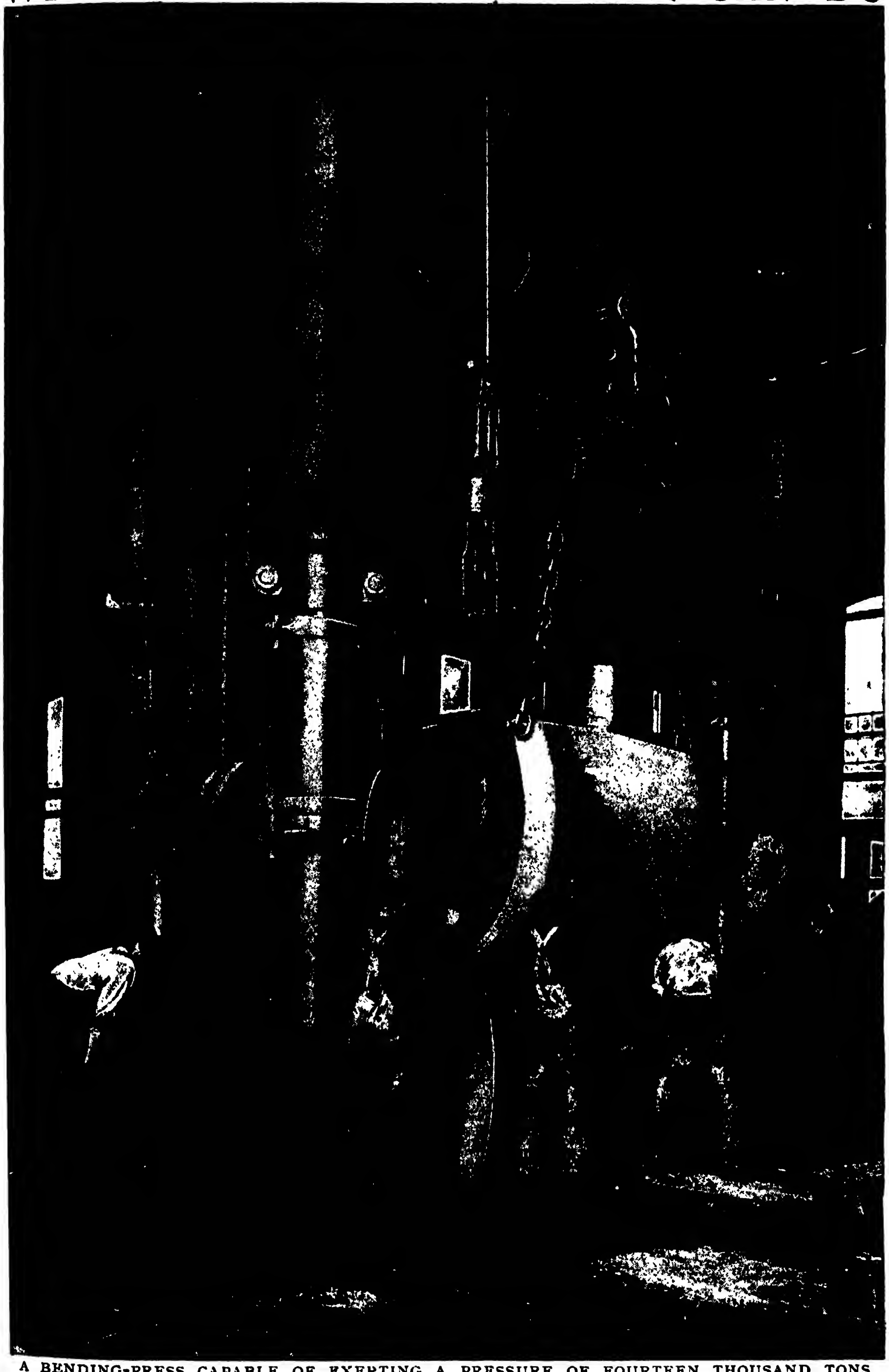
Gas carries the problem of power transmission a stage in advance, because gas can be conveyed in pipes over distances measured by miles. But the gas must be cheap, to compete with steam, and therefore towns' gas cannot enter into rivalry with steam. Only waste gas from furnaces, or gas generated in producers from cheap fuel, can sustain that rivalry. The field of transmission is extended, but only with a rather limited area.

Oil occupies much the same position as gas, because it can be conveyed in pipe-lines, and stored for use. But neither it nor gas can help the problem of transmission very much, because in both cases the engine which transforms the latent energy of the gas or oil into active force is located, like the steam-engine, in one spot, from which the power must be distributed by other means. A steam-engine, or a gas or oil engine, can only do work directly over long distances by being attached to a carriage, which is a development of a different character from that which we are considering.

GRINDING-MILLS WORKED BY WATER-WHEELS ON A CORNISH STREAM

Akin to the steam, and gas, and oil engines are the turbine water-wheels driven by the pressure and momentum of water, due to head, of which we need only mention that the turbines differ from the old water-wheels in being more efficient—that is, they give out a larger proportion of the power latent in falling water than the old water-wheels did. These, however, drive shafting and wheels, etc., in the immediate vicinity, as do the other prime-movers. But, owing to electricity, the use of falling water now

WHAT PRESSURE OF WATER CAN DO

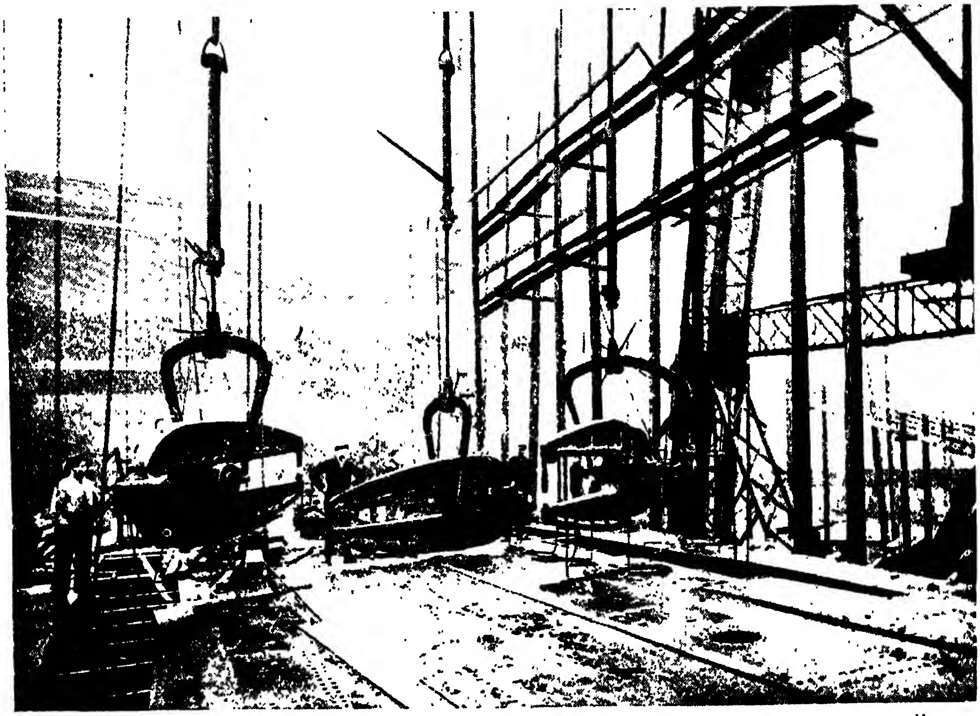


A BENDING-PRESS CAPABLE OF EXERTING A PRESSURE OF FOURTEEN THOUSAND TONS

The photographs on these pages are by courtesy of Vickers, Ltd.; Vereinigte Maschinenfabrik, Augsburg; Harland & Wolff, Ltd.; The Bethlehem Steel Co.; Great Western Power Co., California; British Aluminium Co., Ltd., and others.

occupies a vastly larger sphere than of old. Apart from this last new agent, the employment of turbine wheels would inevitably have increased in countries where water-power is plentiful, and coal costly, but still transmitting power by shafting, pulleys, and cotton ropes or belts. The electric cable, however, has increased the demand for turbine wheels to an extent far greater than this—so much so that in the districts where water-power is abundant no other form of motor is ever installed. Here the water is not the agent of transmission, but the electricity.

Power, however, can be transmitted by pressure-water alone, with scarcely any loss, fans, organ-blowers, centrifugal pumps, etc. One hundred and twenty gallons of this water will do the work of one horse for one hour. Five great pumping-stations transform the water from the Thames and other sources into an agent of vast power, transmitting it underneath London's great arteries, from east of the Tower to Bayswater, from City Road over Southwark Bridge, under Oxford Street, Holborn, the Strand, Farringdon Road, etc., a network of energy which can be tapped by consumers, who are also provided with means for using it at lower or higher pressures than the normal of 750 pounds to the square inch.



HYDRAULIC RIVETING-MACHINES AT WORK ON THE DECK OF THE "OCEANIC"

to a distance of many miles. It has been regularly done in London for more than thirty years past. That is, Thames water, pumped until it acquires an energy of pressure of 750 pounds to the square inch, will do work with nearly the same pressure several miles away, and, of course, also at lesser distances. London is now supplied with a network of 174 miles of hydraulic mains, which deliver 21,900,000 gallons of water weekly to consumers at a pressure of 750 pounds to the square inch, supplying power to 6910 machines, such as cranes, lifts, presses, hydrants, and through turbines for imparting rotary motion to chaff-cutters,

Water transmits its pressure practically undiminished, because it is nearly incompressible. Under high pressure it acts like a solid rod of steel, and the pipes have to be very strong to carry it. A leak only five-sixteenths of an inch in diameter in one of these pipes would waste 3000 gallons per hour, such is the speed at which it would escape. Liverpool, Manchester, and Glasgow and other large cities have similar hydraulic installations, though on a much smaller scale than that of London.

Though water-pressure can be conveyed thus for several miles, it is more often employed over lesser distances. It is used to

transmit power to machines in workshops, and to cranes on quay walls. Most of the coaling of vessels is done by hydraulic cranes, worked by water conveyed in pipes. All steel ingots for guns and armour-plates are compressed by water-power, transmitted through pipes from pumps and accumulators. Every day, in every great centre of industry and manufacture, thousands of operations are performed silently by massive machines actuated by water under pressures ranging from 750 pounds to four tons to the square inch. The heaviest engineer's work is done by this agent. A press at the Bethlehem Works in the United States exercises a total squeeze of 14,000 tons. Big dock-gates are opened and closed by power-water; swinging and lifting bridges also, and much beside. The bascules of the Tower Bridge, each weighing 1070 tons, are lifted from the horizontal to the perpendicular within two minutes by water pumped at a pressure of 850 pounds to the square inch. Canal-lifts in England and on the Continent, loaded with water and barges, are worked by water-pressure.

Allied to hydraulic supply is that of compressed air, conveyed through flexible pipes. It is used for driving engineers' tools of many kinds, particularly in mines and tunnels, and for cranes, but it is not suitable for long-distance transmission.

But electricity transmitted along stationary wires is the latest, and now by far the most valuable, agent of transmission. Its range vastly exceeds that of any other. It is a more flexible agent; and what renders it especially serviceable is the fact that every one of the power agencies which we have mentioned is readily convertible into electric energy on a rotating shaft. The real era of long-distance transmission began as recently as 1893, when electricity, generated by water-power in Sweden, was

WATER RAISED BY WATER—A HYDRAULIC LIFT ON THE NORTH STAFFORD CANAL

THE TRAVELLING CRANES IN A BOILER-MAKING SHOP, WHICH CAN LIFT A HUNDRED TONS

HE MAN AT THE LEVER ABOVE CAN CONTROL TO A NICETY THE LIFTING AND MOVING OF ENORMOUS WEIGHTS BY ELECTRICALLY DRIVEN CRANES

sent ten miles, from the Hellsjön Falls to the Grängesberg iron-mines. The plant of this significant experiment was of 400 horse-power capacity, and it is still at work.

Mechanical difficulties in the translation of either form of power into electricity can be surmounted; the only question that remains for engineers is an economical one —that of the relative cost of different systems. Local conditions largely determine the selection. In England, where coal is cheap, steam-engines usually have the preference, but large gas-engines are better in the neighbourhood of great power-stations that utilise waste gases from blast-furnaces and other sources. In Switzerland, South Germany, and France, in Sweden, California, and Canada, the water-turbine is supreme.

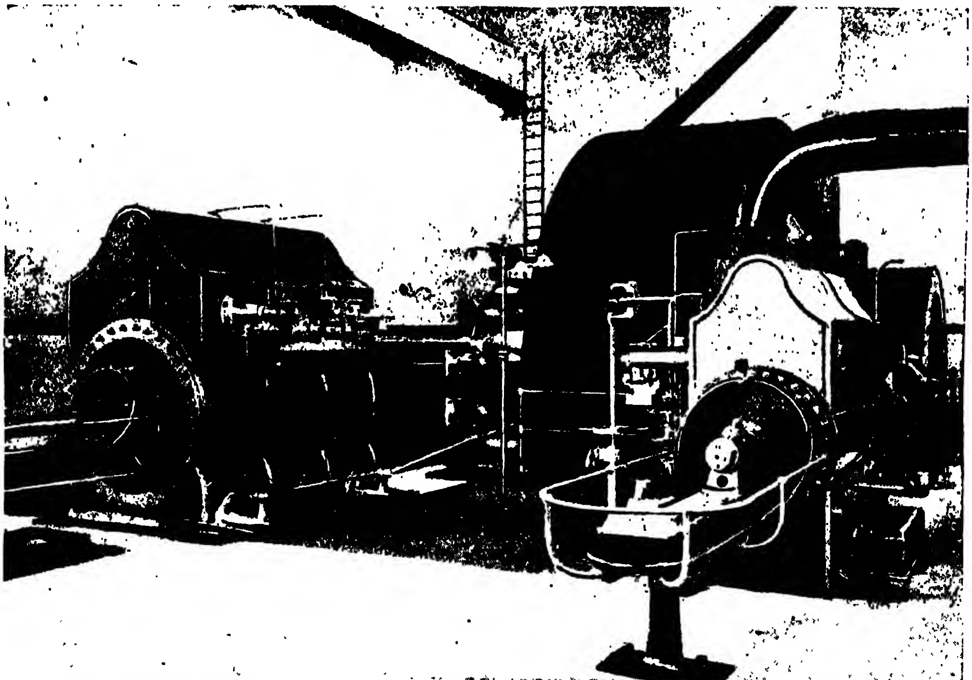
Often the features of transmission to a factory or mill are reproduced within its walls. Then, instead of belts and pulleys and shafts, each machine has its own electric motor, driven by a cable from the main dynamo. But only in regard to the more recently equipped factories would this statement hold good. In many factories, shafts and belts, etc., have been reduced in number, and their place taken by electric cables. Seldom, indeed, wholly replaced, but greatly lessened, and, instead, small groups of machines are still belt-driven, but each group derives power from one electric motor. Only in a relatively limited number of establishments has the full electric drive been installed on the "one machine, one motor principle." Cranes, however, are an exception to this. A form of transmission of power akin to that of tramways and railways is applied to electric travelling cranes, which may either run along on rails or on overhead tracks. Cranes of the latter kind will lift loads ranging from one ton to 150 tons by current conveyed along bare copper wires from any distance. These are located along the sides of the shop, and along the girders which carry the lifting apparatus. Wires of three-eighths of an inch, or half an inch diameter only, yet charged with such enormous capacity!

Once more, it is a remarkable fact, that the biggest users of power in the country, the cotton spinning and the

THE FOREST OF BELTS IN AN OLD-FASHIONED ENGINEERS SHOP

weaving mills, are almost wholly equipped with the old system of steam-engines, shafts, pulleys and ropes. But an explanation of this is not difficult. Such mills are equipped with the very best steam-engines that are built, economical to the last fraction of steam, fitted, too, with an elaborate, highly efficient system of rope-driving, and governed so exactly that the speeds of the machines do not vary by more than 1 per cent., and they are regarded as the last word in high-class engineering equipment. These facts are sufficient to explain why the owners do not welcome an expensive change in plant. swift streams had run to waste since first the morning stars sang together, but many of these waters have now been harnessed to the service of man, and transmuted into light and movement. Always the agent is the cataract or stream, turning a turbine-wheel, rotating a dynamo, and generating electricity, which the wires convey to the distant towns.

Among the most remarkable of the Western Pacific installations are the Snoqualmie Falls, in Washington State, with a transmission of 83 miles; the Bay Counties with 152 miles, and the Standard Electric Company, 154 miles. A part of the latter

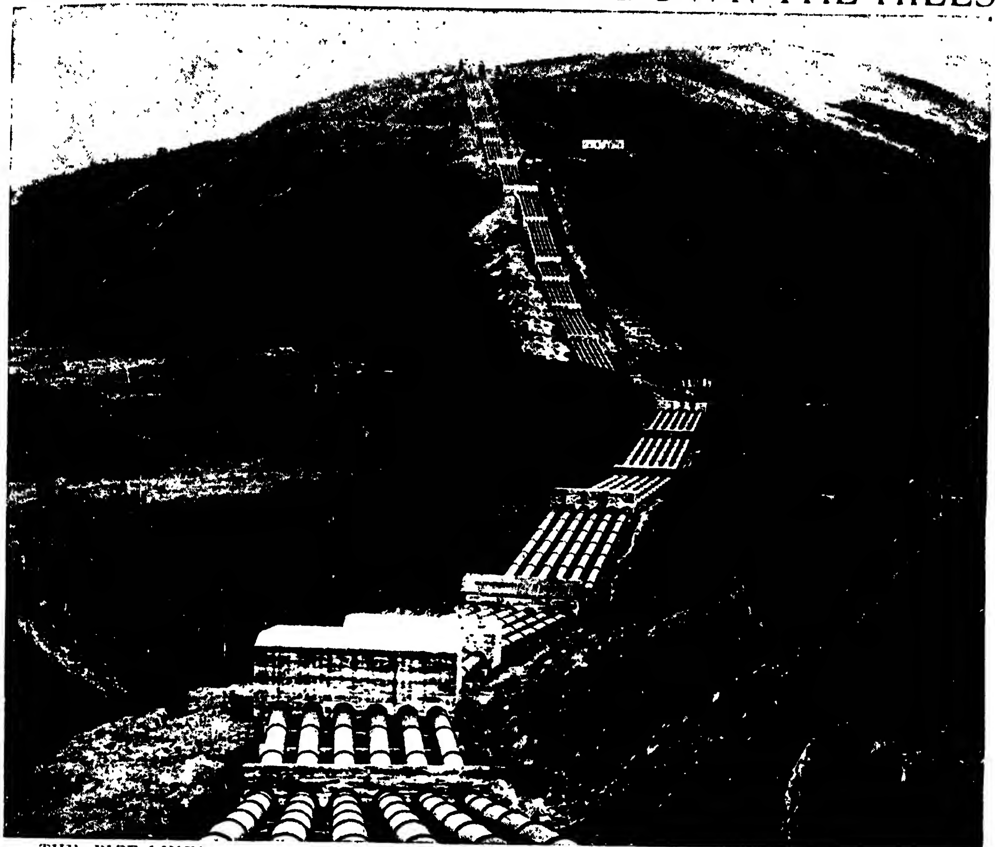


A MODERN MILL-ENGINE DRIVING BY ROPES MACHINERY ON DIFFERENT FLOORS

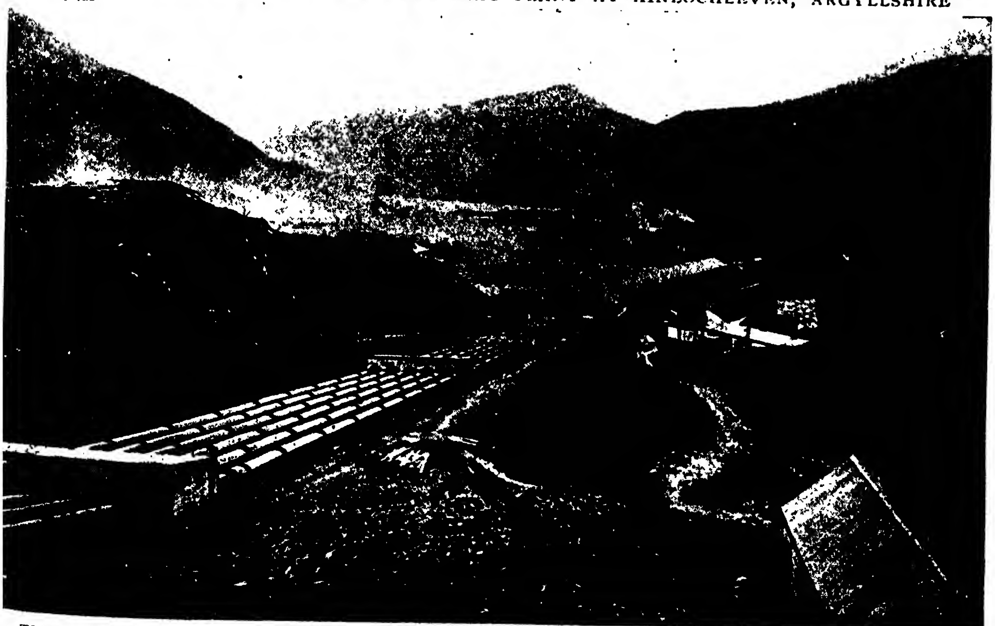
The hydro-electric power installations of Switzerland are numerous, wonderful, and well known to many to whom those of California and the Western Pacific Coast generally are unfamiliar. But the latter are on a far vaster scale, and have been carried out in the face of greater difficulties by pioneers working in dense mountain forests where the axe has had to clear the way for the transmission wires. It is in these Western wilds that the problems of very long distance transmission were solved, for San Francisco first, and afterwards for towns with lesser-known names. Torrents there are in abundance all along the slopes of the Rockies. Cataracts and

used in connection with the Bay Counties has a transmission of over 220 miles. Startling and eerie are some of these installations. The Snoqualmie Falls are approached through a railway that winds picturesquely up into the Cascade Mountains to the town, nestling in a setting of forest and gorge, and lit by the waterfall. Here one must descend 250 feet below the surface in a lift to reach the power-house, located in a cavern in the solid granite rock beneath the falls. In this cavern are six electric generating-machines, and they are so placed as to afford protection to the machines from the everlasting spray from the cataract. Current is thence carried through dense forests of

HOW POWER IS BROUGHT DOWN THE HILLS

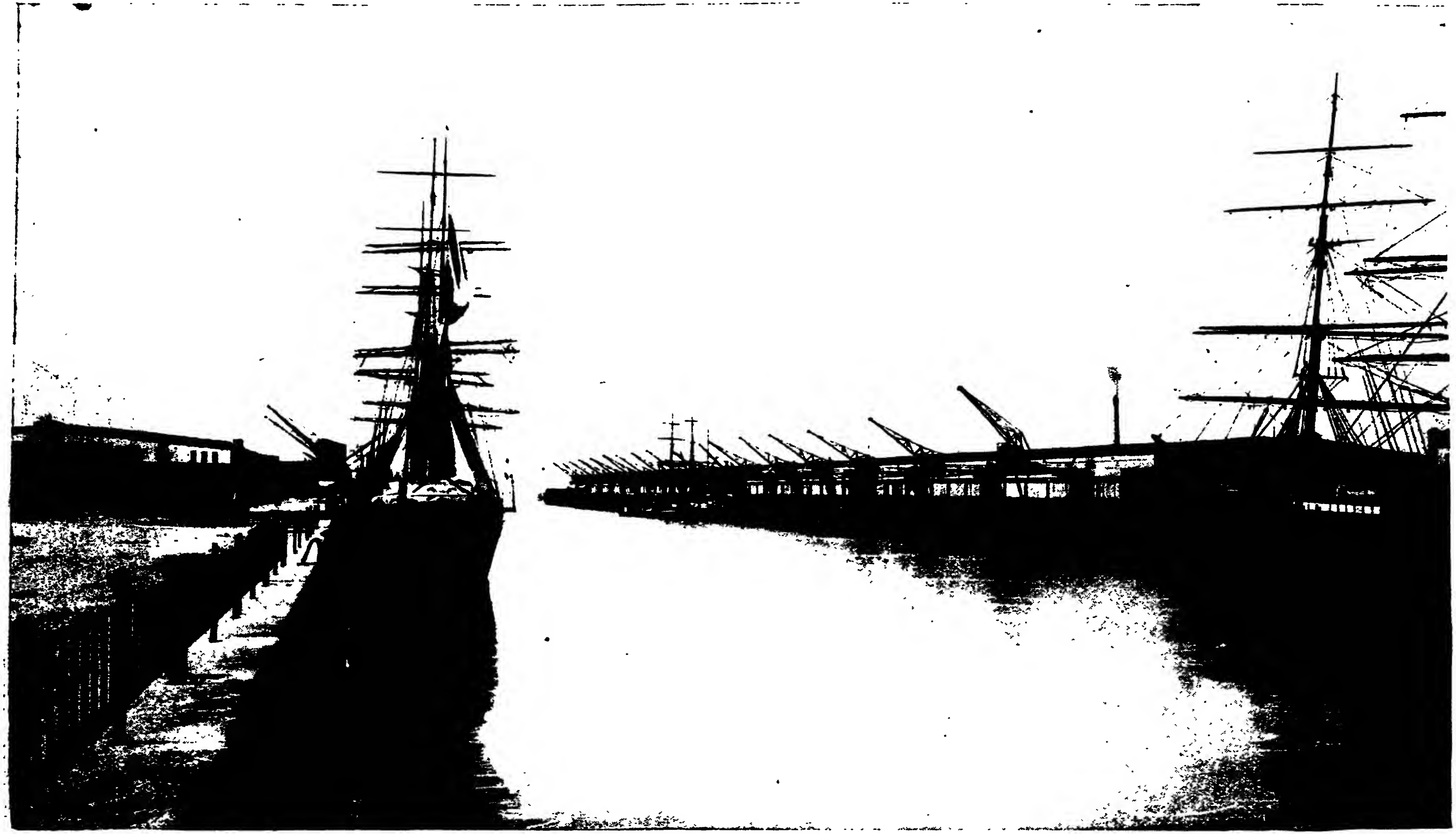


THE PIPE-LINES OF THE HYDRO-ELECTRIC PLANT AT KINLOCHLEVEN, ARGYLLSHIRE



THE INDUSTRIAL VILLAGE OF KINLOCHLEVEN, WHERE WATER-MADE ELECTRICITY IS USED

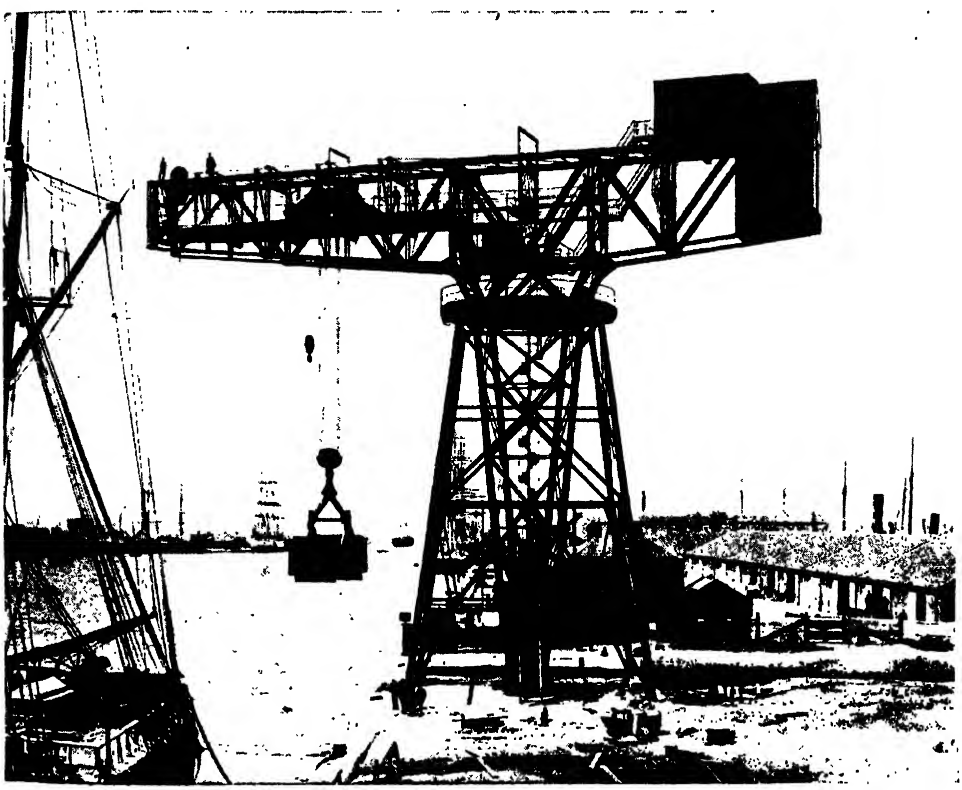
THE DISTRIBUTION OF MECHANICAL POWER TO SUPERSEDE HEAVY MANUAL LABOUR



A LONG LINE OF POWERFUL CRANES ALONGSIDE A GREAT DOCK, ALL WORKED BY ELECTRICITY FROM A CENTRAL STATION

spruce and fir, a broad band having been cleared by the pioneers in order to prevent risk of trees falling on the wires and interrupting the service. This plant provides light and power to the great and rapidly growing cities of Seattle and Tacoma.

In California, especially in the southern districts, are canals from five to fifty miles in length connected to river rapids in the heart of the mountains, often far removed from human habitations. These convey the water under heads ranging from 300 to 1500 feet, to drive the turbines, or Pelton wheels, on the shafts of which the electric generating-machines are coupled. The Standard Electric Company has developed from an earlier scheme, that of the Blue Lakes Water Company, for supplying water to mines in Amador County. The Standard Company transmits power to San Francisco at 50,000 volts. The enterprise involved building storage reservoirs in the high Sierras, 6000 to 8000 feet above sea-level, provided with dams, and capable of storing a supply for 150 days, the maximum dry period in Alpine County. Thence the water is allowed to flow along 50 miles of river channel to a dam, where it is diverted into a canal 25 feet wide, 5 feet deep, and 20 miles long, to the crest of a hill over the power-plant, which it supplies with a head of 1450 feet! The water issues through a tunnel 3000 feet in length, at a velocity of 18,000 feet per minute, and turns wheels 11 feet in diameter at a speed at the periphery of 9000 feet per minute. Thence the current generated is carried through the city of Stockton, and the town of Mission San José, along the shores of San Francisco Bay to a distance of 100 miles from the power-plant. Here the wires diverge north and south, running north about 28 miles to Oakland, and south to San José, around the bay and up to the north to San Francisco, a distance of 154 miles from the generating-station.

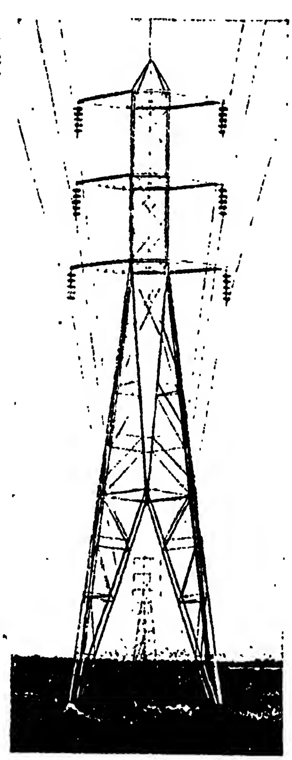


A HUGE HAMMER-CRANE OPERATED BY ELECTRICITY

The Bay Counties Company operate a line 152 miles in length from their plant to the city of Oakland, the most remarkable feature being the crossing of the Straits of Carquinez with cables having a span of over 4000 feet. The Standard

Electric Company buys power from the Bay Counties Company, which they transmit, making a total transmission on the part of this company of 198 miles to San José, of 200 miles to Redwood City, and 218 miles to Stockton. These plants operate railways, flour-mills, mines, and lighting.

The city of Guadalajara, in Mexico, obtains its electric power from the famous falls of Juanacatlan, on the Rio Grande; and the city of San Luis Potosi is supplied with power from a generating-station 200 miles away, by the Central Mexico Light and Power Company, at 100,000 voltage or pressure. The construction and maintenance of such a line in a wild country is one among the many great feats of the electrical and mechanical engineers. The lines must be high up above the ground, must traverse valleys and mountains and rivers. In winter time the snow and frozen sleet will lie heavily on the wires and break them down if ample strength is not given. But every increase in diameter and weight adds seriously to the expense of long lines. The hurricanes will blow the lines down, unless the poles are reasonably near together and well secured in the soil. Plain wooden poles are insufficient when the lines are very lofty. Steel poles are then used instead of wood, and sometimes steel towers. On the San Luis Potosi transmission there are 70 miles of these steel towers. Branches of trees falling on the line will short-circuit it, cutting off the current. Mischievous people will take aim at the insulators, or cut the wires and steal the copper to sell it. Because of these things, a long transmission-line is a cause of daily anxiety to the engineer in charge. It is necessary to keep men patrolling and inspecting the line, each in his own section, with houses for their accommodation. A safe method, but too costly for general adoption, is to have two lines running parallel with each other, not less than a mile apart, the one being a stand-by in case of the temporary failure of the other. Apart from such a provision, the failure of current would deprive thousands of people of service stop trams, and plunge cities into darkness. And the conditions vary in different countries. Lightning is a danger in some parts of America and in the Transvaal. Each tower or pole, therefore, should have a lightning conductor. In some hilly countries, again, landslides are frequent, and floods in others.



TRANSMITTING ELECTRIC POWER IN CALIFORNIA

In transmitting power over long distances the voltage must be high, and then trouble comes in, because high voltages find out weak spots. This is the reason why progress has been tentative, and apparently slow. Ten years ago no one could imagine that voltages of over 100,000 would be common, with transmission to 240 miles. Now some electricians confidently anticipate voltages of 200,000 and distances approaching 400 miles—the maximum need in England.

Power from Niagara is now transmitted to Syracuse, 150 miles away, at 60,000 volts. Yet, when Niagara was first harnessed, the limit of transmission was Buffalo, only 21 miles away. When distances grow, the difficulties of insulation and other practical details become so pressing that it is often better that industries should migrate near to the source of power, or that new industries should establish themselves on the spot, than that very long transmission-lines should be installed. This attraction of industries in the vicinity of the generating-station has happened to Niagara, and largely to our North-East Coast power scheme, and in Switzerland and France. It is estimated that Niagara has an energy of nearly 5,000,000 horse-power. An average of 222,400 cubic feet of water pass over the Falls each second, equal to 25,000,000 tons per hour, or one cubic mile per week. Of this at the present time about 600,000 horse-power is laid under tribute, obtained by turbine wheels of from 5000 to 12,000 horse-power each.

Rio de Janeiro, with a population of 812,000, is supplied with light and power generated 50 miles distant. Fifty-four thousand horse-power is transmitted, at a line-voltage of 88,000, which will be increased in the future. The electricity is obtained from six turbines receiving water

A BOUNTIFUL GIFT OF LIGHT AND POWER

THE SNOQUALMIE FALLS, WHICH SUPPLY ENERGY FOR ONE-THIRD OF A MILLION PEOPLE IN SEATTLE AND TACOMA

from a vast artificial storage reservoir 17 miles long, having a total volume of 7840 million cubic feet. This water is obtained from the Lages River.

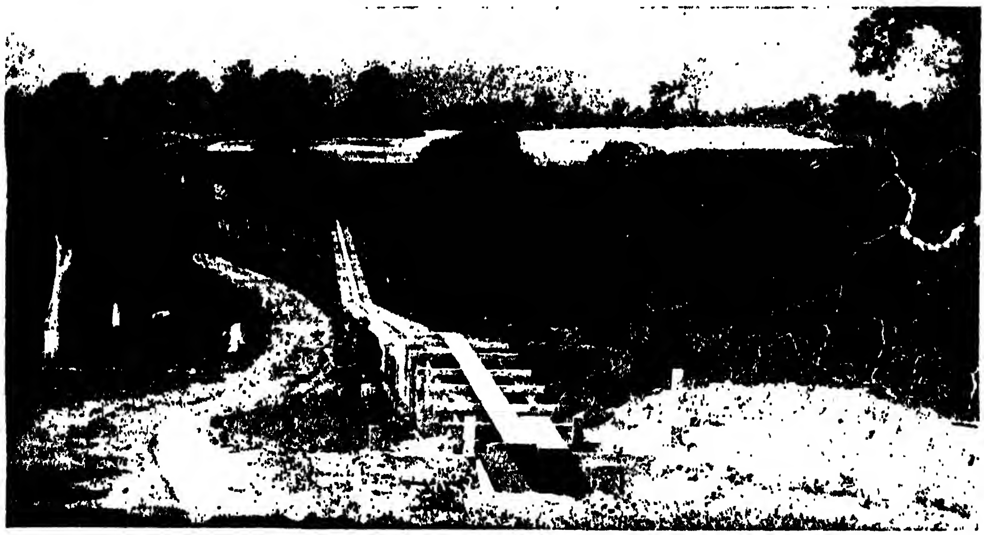
There is a 6300 horse-power transmission system which extends from Montiers to Lyons, a distance of about 112 miles. From an engineering point of view this is a remarkable example of long-distance transmission by continuous current. It drives the tramway system of Lyons, and feeds an existing system previously working there. Two overhead wires convey the power nearly all the distance, until, when within a few miles of the city, they are carried underground. At Molinar, Spain, there is a power-scheme which transmits energy to Valencia and Alevy, over 50 miles; to Cartagena, over 100 miles, and to Madrid, over 150 miles. The pressure is 70,000 volts.

Electric transmission has solved the acute problem of suburban railway and tram traffic in London, Liverpool, New York, Paris, and other great metropolitan cities—so recent and yet so vast are its ramifications! The Liverpool overhead, 1893, and the City and South London Railway, 1890, aroused immense interest, because they were pioneer works, precursors of electrically operated lines that link up the suburbs of the great cities with services of two or three minutes' intervals. Steam-engines are hopelessly and for ever ousted from these services, displaced by the invisible current that renders the electric cable or rails alive. Main-line traffic stands on a different footing, and many sanguine electricians do not anticipate the capture of that—at least, not yet. Twelve miles is usually assumed to be the limit beyond which electrification is not, under existing conditions, profitable.

There are three systems by which electric railways are operated. First, the continuous or direct current system, which, known as the third-rail system, also employs alternating current for transmitting power when long distances are concerned. The City and South London Railway is worked by continuous current at 2000 volts, distributed to the trains by the three-wire system. The up and down track conductors are of opposite polarity, while the track rails form the middle conductor.

Second, the three-phase alternating current system with two overhead trolley wires. The North-Eastern Railway have 30 miles of the Tynemouth lines electrified thus. The track is the return conductor.

Third, the single-phase alternating current high-tension system, with a single overhead trolley wire. The Midland Company's line at Heysham was the first of the kind opened in this country. The 8½ miles of section from Victoria to London Bridge, on the London, Brighton, and South Coast system, recently opened, is the first of the London railways to adopt the single-phase system. Power is supplied, at 6600 volts, through feeding-cables and switch-cabins to overhead track-conductors (using the curious automatic bow collectors). The outer distributing cable is bonded to each length of

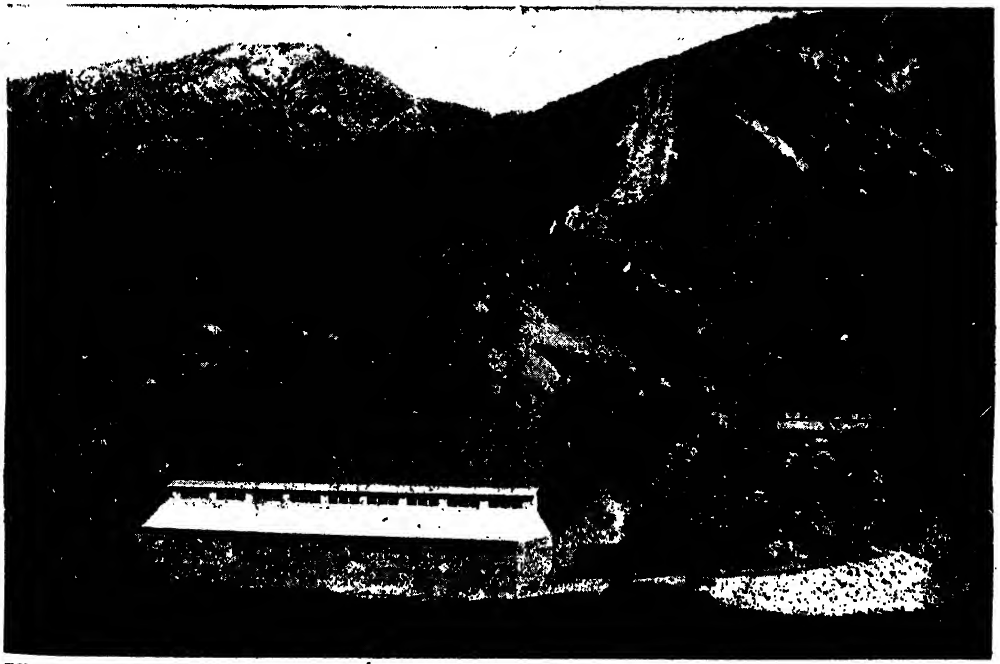


WATER FROM THE SAN JOAQUIN RIVER BEING CONVEYED IN A WOODEN PIPE FROM A STORAGE LAKE TO A POWER-HOUSE IN CALIFORNIA

WHERE LOS ANGELES FINDS ITS POWER

THE SANTA ANA RIVER, IN CALIFORNIA

WATER-ENGINEERS' CAMP



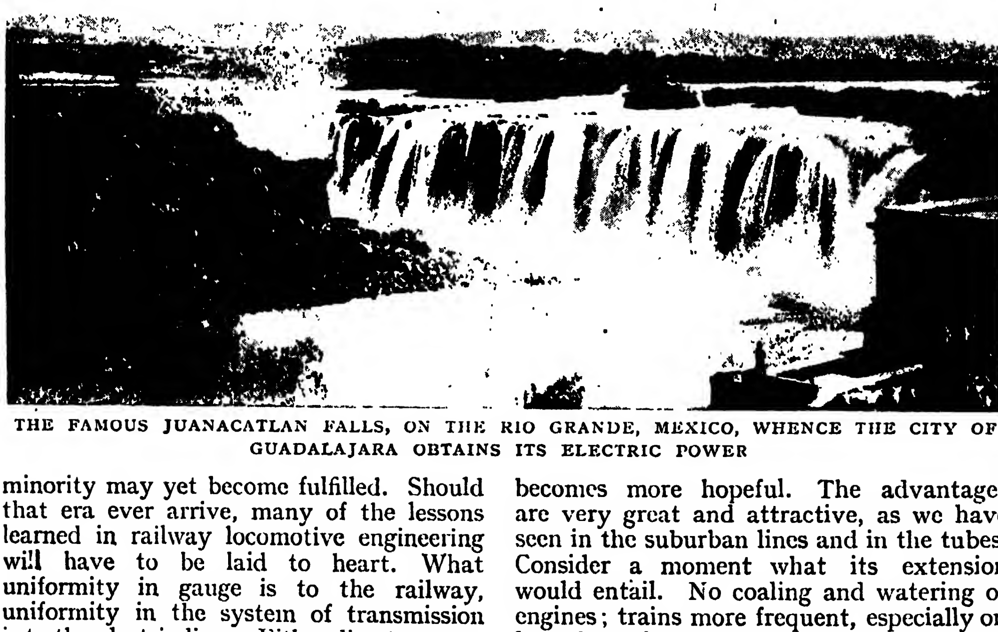
THE POWER-HOUSE ON THE SANTA ANA RIVER WHERE THE TRANSFORMATION INTO ELECTRICITY OF A WATER CURRENT TAKES PLACE, FOR TRANSMISSION TO LOS ANGELES, EIGHTY MILES AWAY

track rail and forms the return conductor. The Central London Railway employs a polyphase system, with conversion to continuous current at sub-stations. Power is supplied to the trains by the third rail, and the track rails are the return conductors. The traffic was originally worked by locomotives, but multiple unit trains are employed instead, using an electro-magnetic system of control.

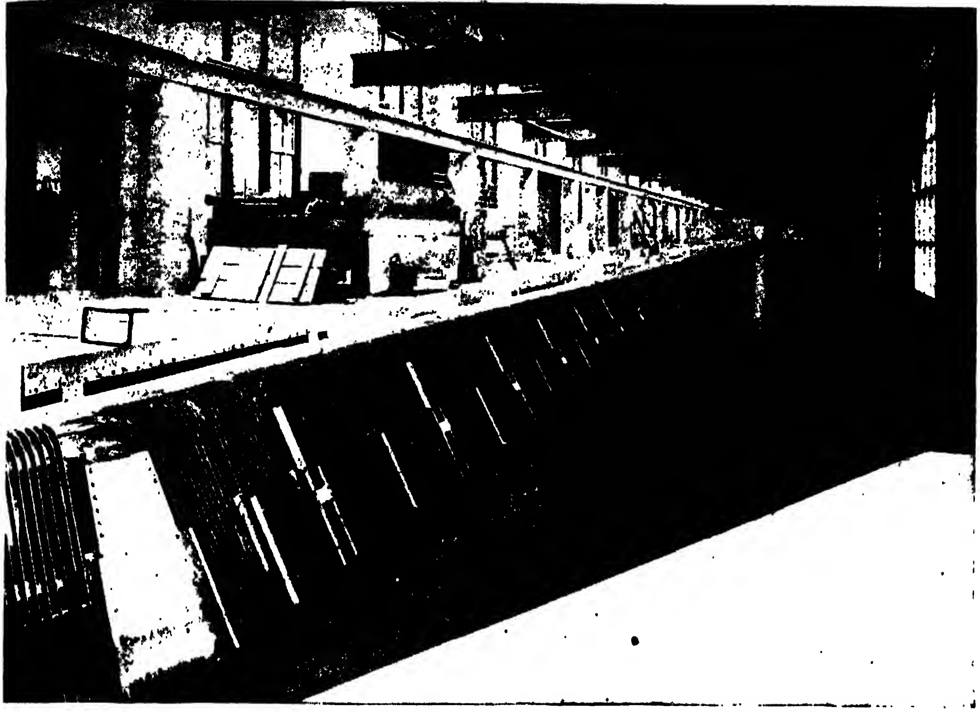
The transmission of power by the electrification of railways, though extensive, is as yet confined to a few short suburban and branch lines. Opinions differ as to the practicability in the future of the electrification of main lines. The views of nearly all railway engineers are opposed to it. Yet some sanguine spirits advocate the system, and the dreams of the persistent minority may yet become fulfilled. Should that era ever arrive, many of the lessons learned in railway locomotive engineering will have to be laid to heart. What uniformity in gauge is to the railway, uniformity in the system of transmission is to the electric line. Either direct-current system, or three-phase, or single-phase system, with all that is entailed in transmission lines and track returns and motors, must be adhered to.

Although we have no water powers in England which would be of any considerable value for generating electricity, yet there are other sources available or in sight. As has been shown in a previous article, vast stores of power can be extracted from inferior fuels and from manufacturers' waste, as is being done on a large scale by the power-companies on the North-East Coast. The growth of the large gas and oil engines opens up vast vistas of cheap power-production. Where gas can be generated cheaply from inferior fuel, as in a producer, and utilised in a highly economical engine like the Diesel, and converted into electric current in a dynamo, the cycle is fraught with immense possibilities. In this direction the future has more promise than that which is held by oil, because of the difficulty in securing permanent and ample supplies of oil at moderate prices. For English engineers must rely on the supplies of power which can be extracted from such sources as are available here.

As the difficulties in transmitting power over long distances lessen, the possibility of great extensions in railway electrification becomes more hopeful. The advantages are very great and attractive, as we have seen in the suburban lines and in the tubes. Consider a moment what its extension would entail. No coaling and watering of engines; trains more frequent, especially on branch services; no smoke or steam to foul the air of tunnels; less difficulty in ascending gradients, since motors are constructed with much excess capacity. Railway companies, too, can co-operate in the erection of power-stations in favoured districts to utilise sources of cheap fuel and convert it into electricity on the spot. Though the time is not ripe for these developments, he would be a bold engineer who, in face of the wonderful growth of the last twenty years in electrified suburban traffic, would predict that main line electrification is impracticable.



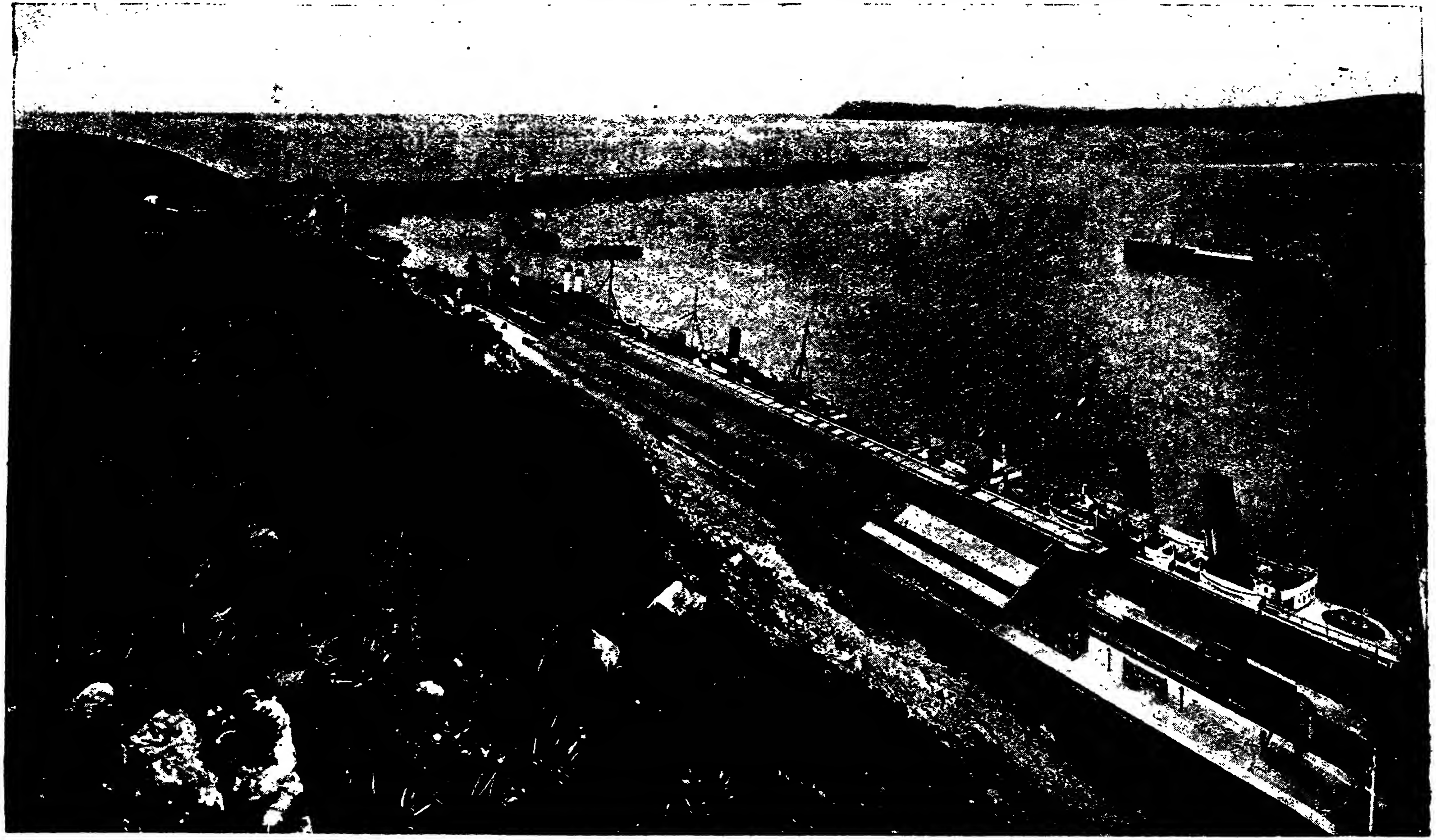
THE FAMOUS JUANACATLAN FALLS, ON THE RIO GRANDE, MEXICO, WHENCE THE CITY OF GUADALAJARA OBTAINS ITS ELECTRIC POWER



THE NIAGARA WATER CONDUCTED FROM ABOVE THE FALLS TO CLEANSING GRATINGS BEFORE ENTERING AND FALLING THROUGH THE PIPES OF THE POWER-STATION

TEN-THOUSAND-HORSE-POWER GENERATORS OF ELECTRICITY WORKED AT THE NIAGARA POWER-STATION BY WATER TURBINES

THE NEW ATLANTIC DEEP-WATER HARBOUR AT FISHGUARD, IN NORTH PEMBROKESHIRE



THE FISHGUARD HARBOUR HAS BEEN PROTECTED BY A GREAT BREAKWATER, TO ALLOW LARGE VESSELS TO LAND THE MAILS FROM IRELAND AND AMERICA

This photograph and that on page 2311 are by courtesy of the Great Western Railway; others are by J. Valentine. S. Cribb, Gibson & Sons, J. & R. Lavis, Frith, and Underwood & Underwood.

FIGHTING WIND AND WAVE

How Bridges, Harbours, Breakwaters, and Lighthouses are Designed to Facilitate Industry and Shelter Commerce

ENGINEERING IN DEFENCE OF INDUSTRY

The winds and the waves are two of the most terrible agencies with which the engineer has to grapple. His work is to oppose to them forces stronger than themselves. All over the world the coasts and islands and shallows are studded with harbours, docks, piers, breakwaters, lighthouses standing four-square to all the winds that blow, and against which the angry waves dash themselves into tormented spume in vain. Bridges and roofs are constructed to resist the highest winds, and against the steel shells of the great ships the immense waves break helplessly into spray, which the vessels shake off lightly as they plough their onward course.

In dealing with the winds and waves as they affect the engineer, while he is safeguarding industry, we assume the reader understands why the wind bloweth where it listeth—that if there were no changes in temperature, or in the humidity of the atmosphere, there could be no winds. Wind pressure has to be resisted in bridges, towers, buildings, cranes, lighthouses, and other engineering works. Often, however, as on the coasts, the waves are immensely more formidable, in the proportion of two or three tons to fifty pounds. Building to resist the waves, the wind may be left out of the calculation.

In the United States the tornado, or cyclone, is the terrible manifestation by which the wind works destruction. It generally travels nearly from south-west to north-east, gyrating on its own centre with amazing velocity, though its rate of travel may not be rapid. It may cause desolation for a width of 300 to 600 yards, and just outside that no damage at all will be done. Monsoons and typhoons are other manifestations of wind-power, happily more or less localised in the East. But with these exceptions the effects of normal disturbances of the atmosphere only have to be provided against.

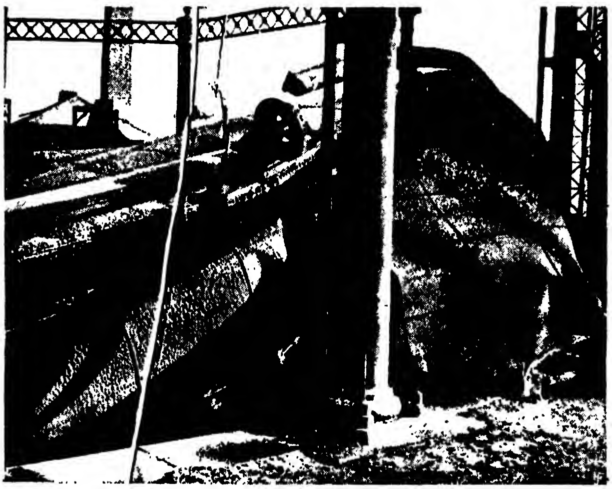
One would think that measurement might easily be taken of the force exerted by the winds. Yet nothing is farther from fact. Since the Tay Bridge was blown over, allowances for wind pressure have been taken at higher rates than are probably really necessary in order to cover and include the element of uncertainty. Previous to that catastrophe the maximum pressure recognised was 40 pounds per square foot. Subsequently the Board of Trade raised it to 56 pounds. Again, wind-gauges do not tell the same story. There were two gauges on the site of the Forth Bridge—a big and a little one. We might have expected them to have registered exactly the same for each square foot of surface. But the large gauge, measuring 20 ft. by 15 ft., on the island of Inchgarvie, 100 ft. above sea level, only registered two-thirds of the pressure shown on a smaller gauge, demonstrating that high pressures are not evenly distributed over large surfaces. At the site of the Tower Bridge there was a difference of 70 per cent. between two gauges.

The pressure of wind is related to its velocity, but in what degree authorities differ. According to one formula, a wind blowing at 100 miles an hour exercises a pressure of 49 pounds per square foot; according to another, only 30 pounds; and the relations of other velocities and pressures vary similarly. In the face of such facts the value of nice mathematical calculation is swamped by the larger uncertainties; and empiricism, guesswork, or what scientific folk call "factors of safety" enter largely into estimates of the force and direction of winds.

On the wild December day in 1879 when the Tay Bridge went down, Professor Grant, of Glasgow University, had been taking

observations of the gale that was raging. At 3 p.m. the hourly velocity of the wind was 24 miles; at 3.30 it was 42 miles; at 4.20, 60 miles; at 6 p.m., 60 miles; at 7.10, within two or three minutes of the fall of the bridge, it was 72 miles. But the Professor entertained no doubt that from time to time sudden gusts of wind brought the velocity up to 90 miles an hour, equivalent to a pressure of about 40 pounds on the square foot.

Various expert witnesses at the subsequent Tay Bridge inquiry estimated that nothing short of pressures ranging between 32 and 37 pounds per square foot acting on the bridge and train could have overturned them. The train itself exposed a large area of surface to the wind, estimated at 1630 square feet. It seems now to us almost incredible that Sir Thomas Bouch, the designer, had made no allowance whatever for wind pressure on the Tay Bridge. He said he thought the greatest pressure likely to occur might be 10 pounds per square foot, and that the bridge had sufficient stability in itself to resist that. Other engineers had supposed there might be a pressure as high as 20 pounds. Sir Thomas Bouch was justly blamed for this error of judgment, since even at that period French engineers were allowing 55 pounds per square foot, and American engineers 50 pounds, for wind pressure.



A GASOMETER WRECKED BY A GALE

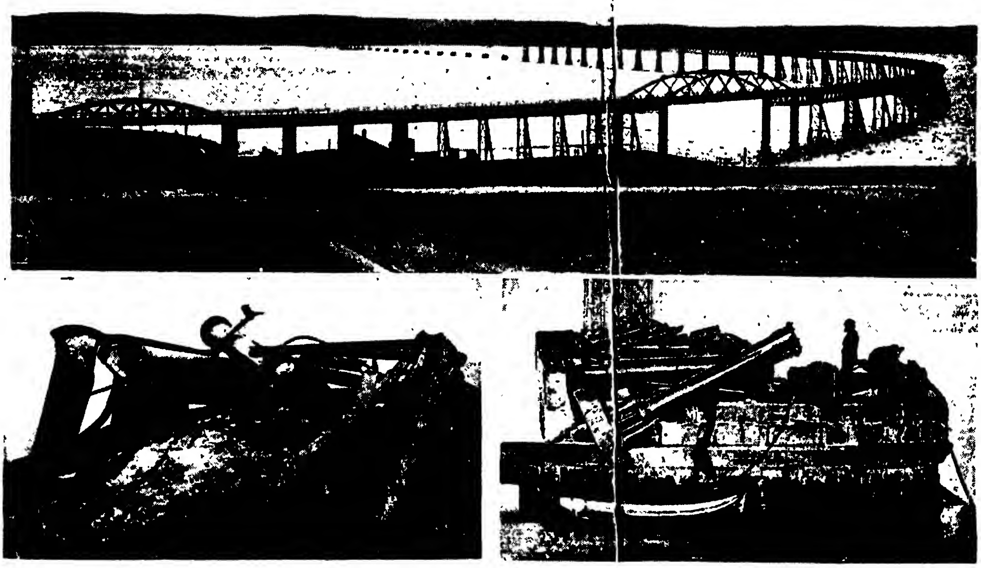
Though the gale was the proximate cause of the overthrow of the Tay Bridge, it was only the proverbial last straw, for the bridge would probably never have gone over but for its wretched general design and the execrable workmanship put into it. It was the wind, however, that was the real and only cause of the overturning of a train on the Furness Railway on February 27, 1903, standing on the Leven viaduct near Ulverston, about 28 ft. above the level of the water. There the wind had an unbroken sweep of 20 miles. Its velocity at Barrow, half a dozen miles away, was 120 miles an hour. All the carriages except the one next the engine were overturned, but out of thirty-four passengers only one was seriously injured. The wind pressure here must have ranged from 35 to 42 pounds per square foot. It is estimated that such pressures would overturn any train in the country.

We see, too, the reason, apart from reduction of dead weight, why large bridges in exposed situations are always built of lattice-braced bars instead of solid plates of iron and steel, as they formerly were constructed. Apart from the very large differences in weight of the old solid girders used for bridges and the present lattice-braced forms, it is clear that the latter expose far less surface to the action of the wind than the older ones did. The wind whistles through the open spaces, but only presses hardly on the narrow bars. It must be assumed to blow on windward and leeward girders alike, or nearly so. The latter may, however, be partly shielded by the passage of a train, so that one half of the leeward area may be left out of the calculation.

But even lattice-girder bridges in exposed situations would be blown over unless wind-bracing were fitted. This comprises bars carried across from the top of the girder on one side to the girder on the other side. Some of the bars are arranged at right angles, others lie between these diagonally, and, crossing, tie each other. Any pressure on one side is thus shared by the other.

Suspension bridges are peculiarly sensitive to the action of high winds. The greatest danger arises, as in roofs in exposed situations, by the wind striking below and lifting them bodily. A bridge of 1000 ft. span over the Ohio at Wheeling was destroyed in this manner. The wind gives rise to undulations of the floor, unless ties are inserted below it. Devices of this kind have therefore been used on long bridges.

When wind pressure is discussed the tact should be obvious, though it is not always remembered even by engineers, that the position of a structure must greatly affect the pressure. There must clearly be a vast difference in the force exercised by the wind on the Forth Bridge and that, say, on Hammersmith Bridge—the one high up on an estuary exposed to the full sweep of the gales from the North Sea, and the other low down in an inland situation. But the same allowance is usually made in all cases, only that where a bridge is greatly exposed more elaborate precautions are taken to ensure its safety under maximum stresses.



THE TAY BRIDGE AFTER THE DISASTER OF DECEMBER 28 1879

The upper picture shows the large extent that was blown away by the wind, and the two lower pictures are near views of wreckage on the piers.

In building the Forth Bridge the wind pressure of 56 pounds on each square foot of area allowed amounted to the enormous total of 7700 tons of lateral pressure on the cantilevers alone. This is a situation where the maximum pressure might conceivably be reached in the gusts of a severe gale. Here the trains are carried about 160 ft. above the waves; and when at the end of one of the cantilevers, a train is 680 ft. away from the cantilever point of support on the pier. The rail level of the Forth Bridge is as high above the sea as the top of the dome of the Albert Hall is above the street, while the top of the structure is 200 ft. higher, or as high as the top ot St. Paul's. But though during the construction of the bridge the wind pressure was observed for several years, the highest recorded never exceeded 35 pounds to the square foot. This occurred during a heavy gale on January 26, 1884. Nothing approximating to this was recorded either before or since, the next highest being 25 pounds per square foot. When the late King, then Prince of Wales, opened the bridge on March 4, 1890, a very stiff gale was blowing. It shook the carriages "as though it would lift them," and caused the visitors a very uncomfortable time. Yet the gale then was only equivalent to a pressure of about 15 pounds per square foot.

The leaves, or bascules, of the Tower Bridge are so carefully counterbalanced that the work done by the hydraulic machinery entails little more strain than the opening of them against wind pressure. Provision is made for the exercise of enough power to open them in about a minute against a wind pressure of 56 pounds per square foot. Actually a pressure of 15 pounds only is ever likely to occur there. Even at this, a total pressure of 140 tons would be

exerted over the whole area of one of the bascules, acting with a leverage of 56 ft.

The only loads to which roofs are exposed beyond the load due to their own weight are that of snow, and the pressure of the wind. Very much must be assumed in regard to wind pressure on these. It is usually supposed to act in a horizontal direction. But as often as not it sweeps downwards, or upwards, and comes in sudden gusts. Hence calculations inevitably become vitiated. Estimates are made on the assumption that pressure increases with the pitch or angle of slope of a roof. This is met by increasing the weight of the roof coverings. But a roof may be lifted off bodily from the walls. In the case of a wall, pressure is assumed to act horizontally and to be concentrated at the centre of gravity of the wall. In tall chimneys the risk of overthrow is met by increasing the thickness of the walls very much from above downwards, so lowering the centre of gravity, and by adopting a tapering outline.

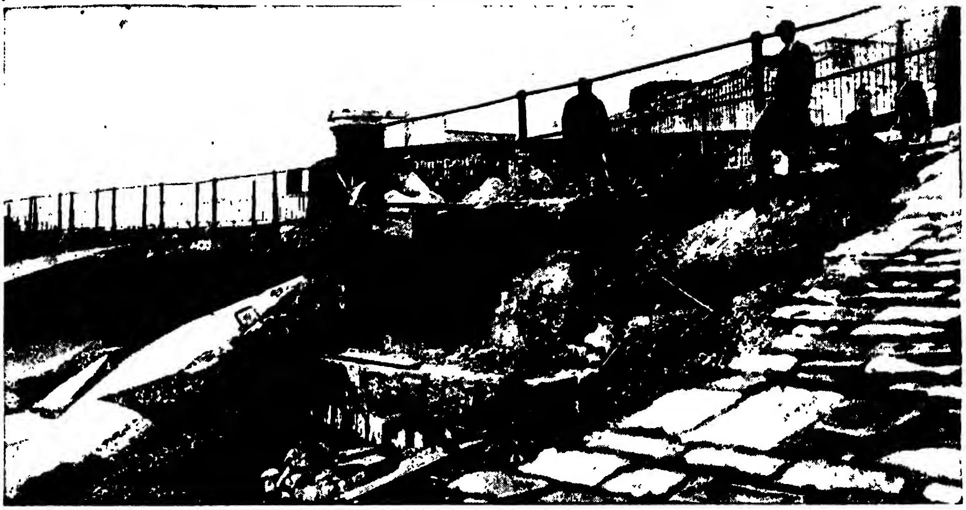
The tall towers of which the Eiffel Tower was the pioneer are exposed to wind pressures in a special degree. That is the reason why the sides and corners have such pronounced curves from the base upwards. A somewhat similar system is adopted in the forms of lighthouses, though here the force of the waves is a more powerful foe than the winds. The members which form the angles of the Eiffel and other towers are really great curved columns, curving inwards to deflect the winds, and are tapered to an exceedingly large amount. The force of the wind is thus expended harmlessly in a vertical direction. This also in the Eiffel Tower avoids the necessity of bracing these members to each other with diagonal bracing. Even under the highest winds the oscillations at the top of this tower do not exceed 5 in. or 6 in. And yet the pressure of the wind is a factor that should never be forgotten.

In this connection the disaster to the great tower at the Nauen wireless station, near Potsdam, may be recalled. In a violent gale in April, 1912, it was blown down, although only completed last November. It was the highest structure in the world after the Eiffel Tower, the height of the latter being 958 ft., while the Nauen Tower reached 650 ft.

Akin to these towers, though not so large, are the giant cranes of the shipyards and docks, and the Titan cranes used in harbour construction. In these allowances have to be made for the force of wind, usually 50 pounds to the square foot, and wind-bracings are fitted. All are constructed mainly with lattice bracing, and stability is

A VIEW OF THE FORTH BRIDGE, SHOWING THE CROSS-GIRDERING FOR WIND RESISTANCE

MAN'S AGE-LONG CONFLICT WITH THE SEA



THE SEA'S POWER WREAKED ON HUGE CONCRETE BLOCKS IN FRONT OF SOUTHSEA CASTLE

PIER, PROMENADE, AND ESCARPMENT FOR THE DEFENCE OF SHERINGHAM, NORFOLK

A BREAKWATER AGAINST THE BROAD ATLANTIC AT BUDE, CORNWALL

CONCRETE PILES SO PLACED AS TO BREAK THE FORCE OF THE WAVES AT SOUTHSEA

secured by tapering outlines from the base upwards, and by keeping the centre of gravity as low down as is consistent with the efficiency of the machines.

The height of waves depends primarily on the force of the wind, but the action continues after the wind has subsided, due to momentum. The height is chiefly due to the distance over which the waves are acted on. This is termed the "fetch," and by it the height of waves may be approximately estimated. On exposed coasts, therefore, the waves are higher than on those which are protected. This is why engineers build breakwaters, and harbours with narrow entrances, and "havens under the hill," within which ships may ride in safety. On the West Coast of Ireland, with a fetch of 3000 miles to New York, the force of the waves is about three tons on the superficial foot. On the East Coast of England, facing the narrow seas that separate us from the low coasts of Holland and Germany, the force is not a fourth of a ton per foot.

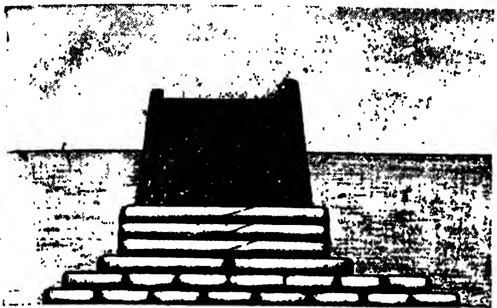
The height of waves is measured from the trough to the crest. Twenty feet in height is a very big wave on an exposed coast, though at sea greater heights are recorded. At Dover waves seldom occur over 15 ft. in height, but at the Tyne they have reached 35 ft., and at Peterhead nearly 40 ft. Sand has been found after a gale in the external gallery of the Bishop's Rock lighthouse, off Scilly, 120 ft. high. At this lighthouse a bell was broken from its attachment, 100 ft. above high-water mark, in 1860. At Unst a lighthouse door was broken open 195 ft. above the sea.

Experiments have given widely different figures for the force exerted by waves. Mr. Stevenson deduced a mean of 1·36 tons pressure per square foot for waves 10 ft. high. Mr. Latham in the same depth obtained pressures of from 18 cwt. to 1 ton per square foot, with winds blowing with a force of from 15 to 18 pounds per square foot. At Cherbourg the pressure in storms has ranged from 600 pounds to 800 pounds per square foot. Mr. Stevenson found the average force of Atlantic breakers in summer to be 611 pounds to the square foot, but in winter it was 2086 pounds. Sometimes 3 tons to the square foot was measured, and at Dunbar, on the East Coast of Scotland, $3\frac{1}{2}$ tons, the sea here broadening and deepening.

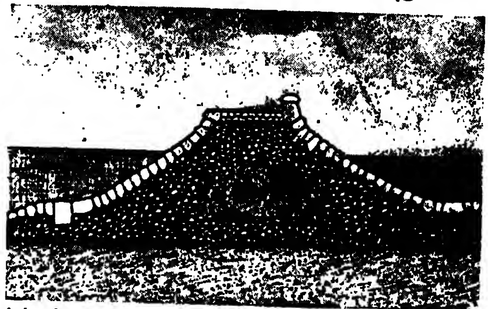
Engineers have to ascertain carefully the highest and lowest spring tides when they build structures having their foundations below the sea, because destructive wave-action extends many feet below the surface of low water. The tides in the open ocean produce waves of oscillation only. That is, they rise up and down merely. The tidal elevation, however, travels at a great speed—at 500 miles an hour in the broad Atlantic. But it travels at 80 miles per hour only

THE CARRIAGES OVERTURNED BY THE WIND ON THE LEVEN VIADUCT, NEAR ULVERSTON

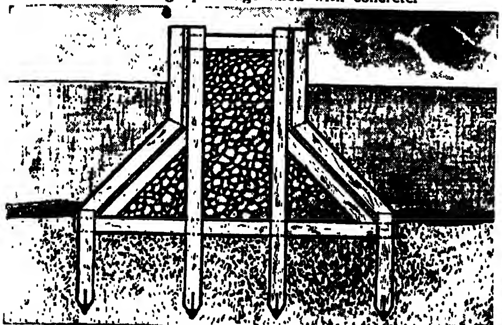
PARRYING THE STROKES OF THE SEA



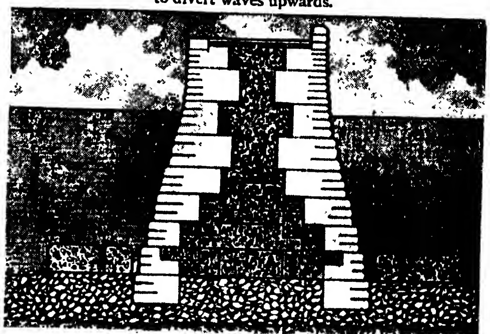
A pier of one solid concrete block, that has been made in a mould, resting upon bags filled with concrete.



A breakwater or pier built of rubble, faced with stone, and sloped to divert waves upwards.

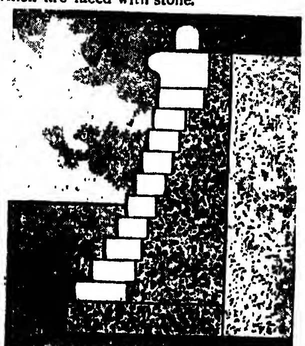


A common form of groyne or breakwater, formed of wooden piles and planking, with rubble enclosed.

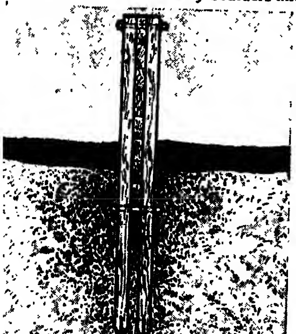


A pier built on rubble with an interior formed of blocks of concrete which are faced with stone.

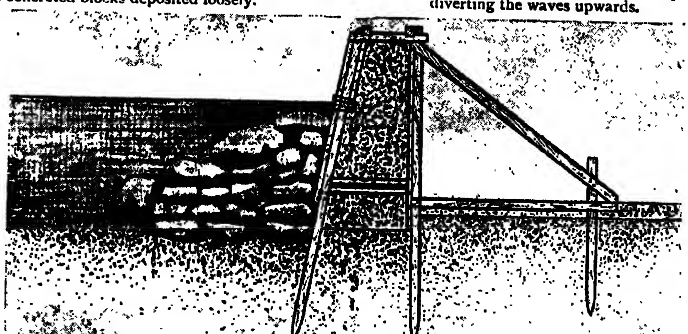
A sea-wall constructed of concrete blocks built on rubble and protected from the force of the waves by boulders and concreted blocks deposited loosely.



A sea-wall on a rocky base, the steps diverting the waves upwards.



A simple groyne formed by double piling and horizontal planks

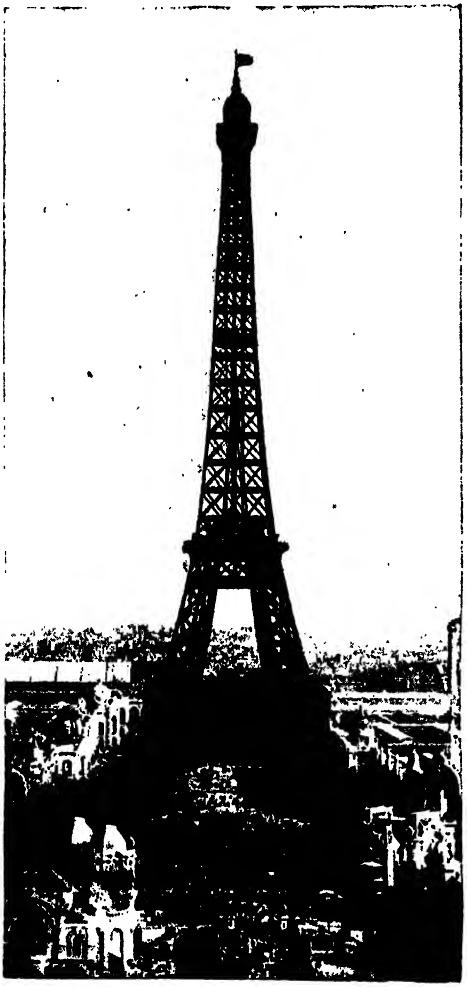


A temporary barrier to reclaim from the sea an area for docks, constructed of timber piles, which enclose puddled clay and sand, protected by boulders that break the waves.

SOME OF THE METHODS FOR STRENGTHENING THE LAND'S DEFENCES AGAINST THE SEA

between the Scilly Isles and Portland, and between Portland and Selsey only 14 miles an hour. When the wave enters a shallow sea, and encounters the friction of the bottom, its height and force increase, while its rate of travel is lessened. The waves then become waves of translation, advancing and receding, and gaining destructive power.

The reason why civil engineers want to know the force of waves is that breakwaters and piers must be built to withstand their attacks. And of late years some old ideas have had to be modified, consequent on the lessons of failures. Formerly, it was believed that wave effects did not manifest themselves at a greater depth than 15 ft. below low water. That error was responsible for considerable damage to some of the older piers and breakwaters. At Tynemouth pier the foundations, which were laid 21 ft. to 24 ft. below low water were badly damaged, and the pier consequently had to be reconstructed. At Colombo an old breakwater founded 20 ft. below low water was replaced by one founded 31 ft. below. In 1896 a block of concrete at Peterhead, weighing 45 tons, lying 30 ft. below low water of spring tide, was carried away. In January, 1897, at Peterhead, blocks weighing 40 tons were displaced at a depth of 23 ft. 7 in. below low water. In 1898 another block weighing 41 tons, and lying 36 ft. below low water, was displaced. A portion of the breakwater, lying 10 ft. 7 in. below low water, and weighing 3300 tons, was twisted to the extent of 2 in. without disturbing the joints in the mass itself. The surface on which the sliding took place measured 33 ft. by 34 ft., and the water dashed up to a height of 120 ft. The length of the waves was 580 ft. to 600 ft. It was estimated that the force exerted on the mass to produce this movement was 2310 tons, or, say, 2 tons per square foot. At the harbour works at Wick in 1872 a mass of solid concrete weighing 1350 tons was shifted and carried by the waves to the leeward of the breakwater. Again, in 1873, another mass of concrete, which had been substituted for the other, and weighed about 2600 tons, was carried away.


THE EIFFEL TOWER, PARIS

When the maximum force of waves on an exposed coast has been ascertained, the problem of building in such a way as to offer sufficient resistance to them arises. The effect of the wave action against the superstructure is largely controlled by the depth of water, and also by the slope of the work that lies below the surface. Against a perpendicular face, with deep water adjacent, the ordinary ground-swell waves retain their maximum depth, and fall up and down as oscillating waves. But storm waves are waves of translation, and these have attained depths from crest to trough of from 15 ft. to 40 ft. These are the waves, from 200 ft. to 600 ft. long, that detach massive concrete blocks and undermine the foundations. But even the ordinary ground waves do considerable damage to the foundations unless these are protected with wave-breaking blocks. Ground-waves, otherwise harmless, become broken up into destructive waves of translation in shallow water. While at high tide they simply range up and down in undulations against the walls of a pier or breakwater; as the tide lowers, the same class of wave will

become broken on the shallows, and act like storm-waves of translation. The rule governing the depth of waves is that their height cannot exceed the depth of the water over which they travel. They therefore break on entering water the depth of which does not exceed their height. Hence long ground-swell waves as well as storm-waves become more dangerous as they enter shallows. The friction of the bottom causes the crest to break away, and to be dashed forward with the velocity of movement of the wave. Arrested by a pier or breakwater, they either inflict damage on it or dash up 80 ft. or 100 ft. high in spray. This explains why a shelving, shallow bottom must either be avoided, whether natural or artificial, or else it must be protected by wave-breaking blocks with enormous powers of resistance.

These are the important facts the engineer has to ascertain and bear in mind when he is constructing harbours and sea protection works within which great ships may ride in safety. If he is able to take advantage of a site that is sheltered in some degree from the full force of the gales, then he will avail himself of it. But very often such favourable circumstances do not exist. Some of the greatest harbours of the world lie in exposed situations. Dover, Colombo in Ceylon, Madras, East London in South Africa, Vera Cruz, all lie exposed to the fetch of broad seas or oceans, and on coasts that are lashed by furious gales. storms, or monsoons.

The masonry of the piers and breakwaters is herculean in character, and its foundations are laid broadly below the scour of the deepest waves and currents. Just how to carry out the details of such work depends on local conditions, and its design taxes the highest skill of the most experienced engineers. That, too, explains why nearly all such works are monuments to the abilities of men whose reputation has been gained in or past middle age. There is so much of experience to be gathered that the earlier and the best years of life have to be spent in subordinate positions, performing the tasks which prepare for the later successes of a most strenuous life.

It is impossible to state here the local features which characterise all the great harbours of the world. Only in general terms can the nature of the schemes be outlined. The object in all cases is to secure the equivalent of a land-locked bay with deep, smooth water—a natural harbour. Consequently, the nearest approximation to this is one which can be completed by artificial methods, at the least expense. Sometimes this condition exists, as at Plymouth. But often hundreds of miles of coast may be searched in vain for any semblance of a natural harbour, as happens along the coasts of India and western South America. Small harbours, too, which might have sufficed fifty years ago, can no longer be utilised, because the dimensions of

BEACHY HEAD LIGHTHOUSE

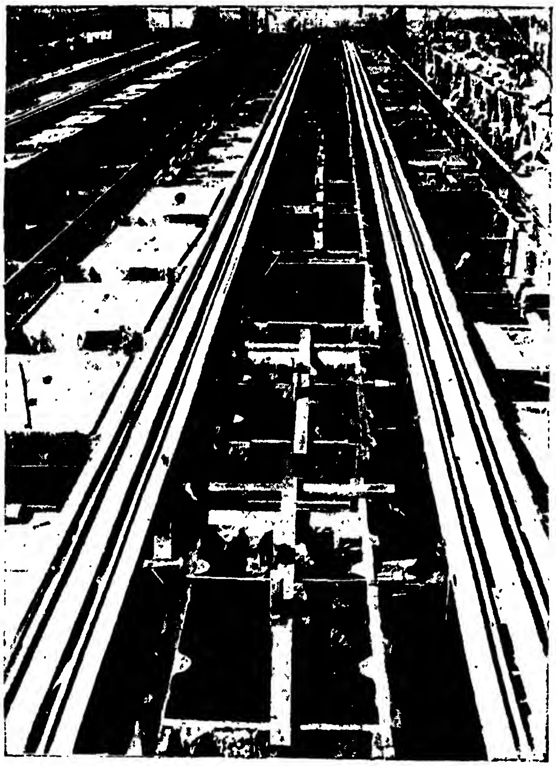
ships and the volume of commerce and travel have so vastly increased. This is the reason why, during thirty years past, there has been a boom in harbour construction all over the world.

If a natural deep bay exists, sheltered on its sides, but open to the sea in the front, it can be converted into a harbour by building a breakwater across the entrance,

leaving a space or spaces wide enough for the manœuvring of vessels entering and leaving. If, however, a deep bay is not land-locked on either side, moles or piers are run out to afford lateral protection. A breakwater may still form a portion of the protection, or the moles may be curved towards each other, leaving a sufficient opening for ships. Or it may happen that one side of a harbour may be protected by a suitable coastline, and then one mole will be built on the other side, with or without a breakwater. If the harbour is not deep, it must be dredged, no matter whether the bottom be rocky or sandy; and this work is so expensive that it may often condemn a site that would otherwise be highly desirable.

Another objectionable feature is the silting up of a harbour, by sand, after its construction. If the accumulations of sand are arrested by the mole or breakwater, they need cause no anxiety. But if they are driven directly through the opening or openings into the harbour, a constant outlay is necessary to remove them by dredging. Hence, in building moles or breakwaters, protection from silting up enters into the engineer's calculations. Months of observation and consideration of alternative methods are thus often spent before any working drawings can be outlined.

As in nearly every locality different conditions are present which have to be met by varied engineering schemes, so in the construction of piers, moles, and breakwaters methods must differ. These are very numerous, but they may be classified under broad types to correspond with the specific conditions that exist locally. Rubble-work is the oldest way of constructing breakwaters. Broken stone is tipped into the sea in vast quantities until it rises above the level of high-water mark. Enormous amounts are required, and almost unlimited supplies of labour, because the stuff must not only acquire the natural slope that loose materials assume, as seen in railway embankments, but additional material must be thrown in about the base to afford protection against the action of the waves. Only where stone is plentiful, and labour cheap, as at Portland and Plymouth, are breakwaters constructed in this crude fashion. A natural work of this kind is the Northern Pebble ridge at Westward Ho! Here the sea, with a fetch of 3000 miles, has rolled up a beach in Barnstaple Bay of great, rounded pebbles all lying at a natural slope. Some of these weigh more than a hundredweight.


MOULDS FOR 40-TON CONCRETE BLOCKS, WITH GRANITE FACINGS INSET

Tipping rubble into the sea has not been satisfactory. Many partial failures have occurred consequent on the undermining of the base by the wasting away of the rubble. The foundation should be as stable as the superstructure; hence the modern practice is to either build with massive concrete blocks, or to face a rubble hearting with concrete blocks—"wave-breakers"—or to build on bags of concrete which solidify. A frequent method is to build up a foundation of rubble 30 feet or 36 feet deep below low-water mark, and complete the structure by building a wall on that of masonry or concrete. There is one disadvantage in this method—the risk of cracks developing in the masonry in consequence of subsidence of the loose rubble. To prevent this, the blocks of masonry are often laid at a considerable

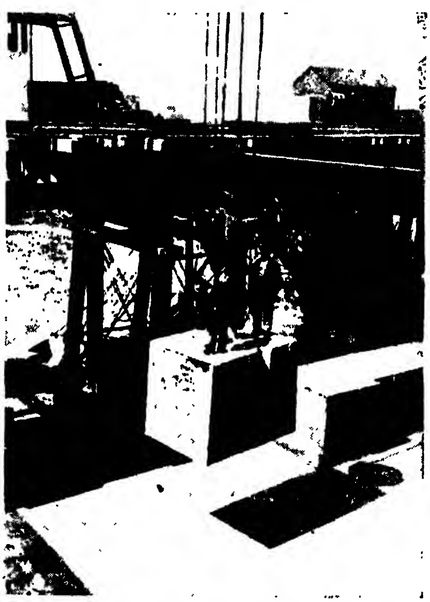
DOVER'S GREAT ARTIFICIAL HARBOURS

The harbours at Dover, on a comparatively open coast, are among the world's finest examples of protected moorings for ships. They are surrounded by about two and a half miles of breakwaters, which cost over three and a half millions sterling.

slope, the better to accommodate themselves to settlement by the sliding of the courses over one another. The masonry is usually composed of cubical blocks of artificial concrete moulded and hardened, though granite facings are commonly used for the top edging courses.

Both these methods are suitable when the bottom is soft and yielding. An alternative, growing in favour during several years past, is to lay the foundation with bags of concrete. This has been done at Newhaven, and at many other harbour works since. The bags are of jute, each holding 100 tons of soft concrete. The bag retains it in place, and the sea water, percolating through, hardens it into a solid mass. The great advantage of this method is that the bags accommodate themselves to the inequalities of the bottom, and as they are piled one above another the last bag laid is level enough to build solid concrete-work upon.

But when the bottom is of solid rock, and the depth of water not too great to permit of divers going down, the rock is levelled, and concrete blocks are laid directly upon it. This is how the piers and breakwater were built at Dover. Two methods of building concrete walls are adopted. The more common one is to mould the concrete in great wooden boxes in cubical masses weighing anything from 25 tons to 50 tons each—40 tons being the most common weight. These, when dried and hardened, are laid like squared masonry, with closed joints, and, if under water, by divers, They are united by a thin concrete grouting which fulfils the function of mortar. But it is poured into grooves, made in the meeting faces of the blocks, and this, hardening, forms a series of keys. It is very unusual for the massive blocks laid in this way to become detached from their position in the wildest weather. If that ever happens, it is generally due to movement of the foundation.



PLACING 40-TON CONCRETE BLOCKS INTO POSITION AT DOVER

The other method, employed much less, is to make a kind of mould of timber outside the width which the wall is to occupy, and to fill the whole of the space with liquid concrete. This hardens and forms a solid wall. Though this might seem a better job than building up a wall with separate blocks, it is not so, in fact. Cracks develop, due to cold, causing contraction of the mass. Provision is made to counteract this by building in steel rods, and leaving joints at intervals, but the method is not so often practised by engineers as the separate block system.

In breakwaters, moles, and piers, by far the larger part of the work lies buried. Millions of money are thrown into the sea every year in engineering works. Submerged materials weigh less than the same materials above water, hence large quantities have to be used to ensure stability. The difference between the specific gravity of masonry and of water causes the masonry to weigh less by about two-fifths in water than above it. Breakwaters are like icebergs—the portion showing above the water is only a small fraction of that which lies below. The breakwater at Fishguard stands only 20 ft. above the water at high tide, and is 70 ft. wide. But it is 80 ft. deep, and 300 ft. wide at the base. This breakwater, 2000 ft. long, swallowed up about one and a quarter million tons of material.

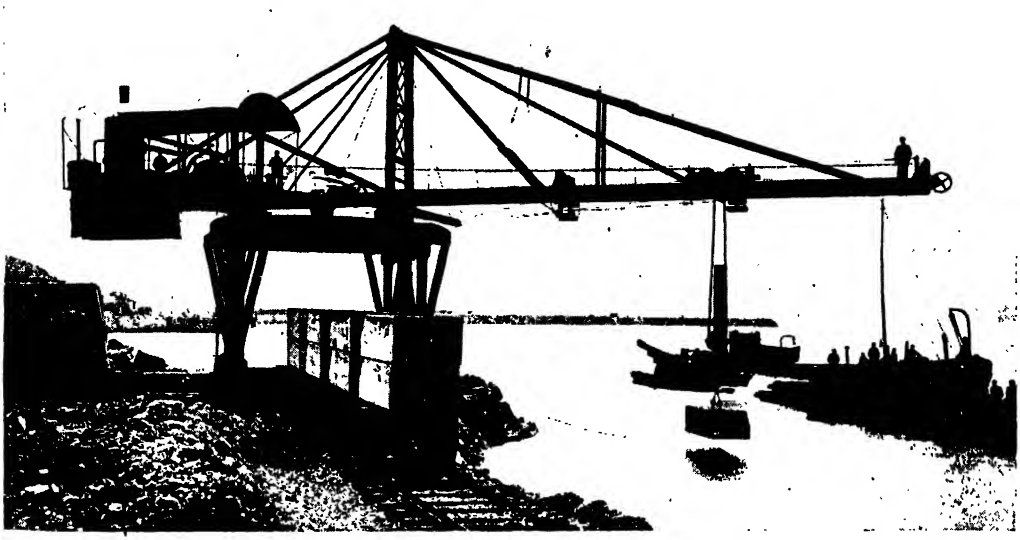
Harbour works and docks are ever in progress all over the world. The older harbours were not at all like those now required for mammoth liners and battleships. These are built of vaster dimensions, and in a more methodical manner. In Great Britain, India, South Africa, South America, and elsewhere many millions of money have been sunk in harbours, docks, breakwaters, and lighthouses.

One of the greatest works of this kind is that at Dover, enclosing a harbour of 610 acres at low water, and 690 acres at spring tides, an area larger than the City of London. Within it a fleet may ride securely, guarding the gate of the North Sea and the English Channel. It is a work which occupied eleven years, giving occupation to between 1000 and 1800 men, and costing $3\frac{1}{2}$ millions of

money, mostly buried beneath the waves in the shape of blocks of concrete. Of that material, 1,300,000 cubic yards were used, besides 260,000 tons of cement and 1,900,000 cubic feet of granite. The Admiralty Pier measures 45 ft. wide at the top, and 57 ft. at the base. The eastern arm is 47 ft. wide at the top, and 54 ft. at the base. These stretch out into the sea, affording protection from west and east. At the south a breakwater 4212 ft. long affords protection. It is 40 ft. wide at the top, and 52 ft. at the base, leaving openings of 740 ft. and 550 ft. wide, through which at spring tides 17,000,000 tons of water rush.

Who knows where the harbour of Tanjong Priok is? It is the harbour of Batavia. A fearsome history it has. It was dredged on the site of an old mangrove swamp, and the stirring up of the mud produced Java fever, and some thousands of men perished. Yet it is now one of the finest harbours in the world. So it should be, for with its breakwater it cost over two millions sterling.

There are apparent fashions in engineering. But it would be more correct to say that practice changes as experience increases. This is exemplified in lighthouses. Everyone knows that Smeaton is credited with having borrowed the idea of his Eddystone lighthouse from the trunk of a tree. The object was twofold—to divert the force of the waves and dissipate them upwards, and to lessen the oscillations of the tower. And but for the disintegration of the rocks on which it was built, the lighthouse would have been standing today, instead of ornamenting the great historical esplanade at Plymouth. But lighthouse construction is now based on later and wider experiences. There are two common designs. In the first, the shaft curving upwards directly from the base is, instead, mounted on a rather tall mass of solid perpendicular-faced masonry. The object in this is to oppose inertia to force, to break the waves up and dissipate them into spray at the base, instead of at the top, where they would obscure the lantern. Another result of equal value follows. The foundation being widened, and the tower itself being shortened, the centre of gravity is brought correspondingly lower down, and the tower will rock less in stormy weather. For the same reason, very tall chimney-stacks are built on a square base. But these stacks will oscillate, in high winds, as much as from 6 in. to 9 in. at the top.



LOWERING A CONCRETE BLOCK INTO THE SEA FOR A DIVER TO PLACE INTO POSITION

In the second design for lighthouses, an open lattice-work construction of steel is adopted, between which the waves and winds rush without inflicting damage. In effect it is a cluster of columns in the sea, and it resembles in its essentials the towers built on land, or the cantilevers of bridges. Many years ago, a structure of this kind at Bishop's Rock was swept away in a storm. It was of columnar form, consisting of a central column and six encircling ones, all of iron, and all connected with bracings. It was supposed that the waves rolled so high that they overlapped the columns, dashed against the solid structure of the lantern, and overturned the structure. There are several lighthouses still of this type.

UNDEVELOPED ENGLISH WATERWAYS

THE DRY BED OF THE DISUSED WENDOVER CANAL

A TYPICAL SCENE ON AN ENGLISH CANAL IN PARTIAL USE

ARTIFICIAL WATERWAYS

The Use of Canals for Trade Facilities Abroad Compared with Our Neglect of Them in Britain

A NATIONAL DEVELOPMENT TASK AHEAD

We have surveyed the two greatest ship canals of the world, the one completed forty years ago at Suez, and the other to be completed at Panama by 1915. We have seen that, much as the work of De Lesseps at Suez did for the world, the mighty task which he began at Panama will do more. We observed in concluding the last chapter that the world's Governments would undoubtedly in future be constrained to exercise a larger authority over such projects, and to attempt a wider control of the forces of Nature. We shall presently find that in the United Kingdom itself work of a similar character awaits the hand of the statesman.

Let us first see what has been accomplished abroad in the creation of artificial inland waterways.

The Suez and Panama ship canals make connection between great seas, and affect trade on a world scale. They have international importance, and their economic influence tells in many lands and upon nearly all industries. A minor, but exceedingly important, part is played in the world by internal navigations, which, while they affect international trade only by modifying the competitive power of various nations, have a profound importance upon the national economy and economic development of the countries which possess them.

Inland canals of international character are the St. Mary's Fall Canal (or "Soo" Canal, as it is familiarly called), at Sault Sainte Marie, and the Canadian Canal, at St. Mary's River, which both connect Lake Superior with Lake Huron on the North American continent. The boundary line between Canada and the United States runs through the St. Mary's Rapids, which lie between Ontario and Michigan and connect the Great Lakes. The effect of the two canals at St. Mary's upon the trade of both countries and upon the machinery of trade has been marked. Commerce and industries have alike been created by this wedding of the great inland seas. The Lake region is wonderfully rich in minerals. The artificial navigations made the iron ore of North Michigan and Wisconsin cheaply accessible to industry. As a consequence, a great Lake shipping has sprung up, and a great Lake shipbuilding industry has been established—an industry protected in the most thorough possible manner by the circumstances.

Water carriage is cheap, and the iron manufactures of Ohio, Pennsylvania, and Illinois have been greatly assisted by the "Soo" Canal. The development of the Lake iron regions made traffic for the Lake steamships, and furnishes the metal out of which the steel vessels are made. The use of the steamships has lowered freights, and therefore reacted upon the American iron and steel industry. And not iron and steel alone are concerned. An enormous quantity of grain passes through the "Soo" Canal, and low water-freights from Duluth to Buffalo play no small part in the economy of the grain trade. Coal, copper, and timber have also been affected. Simultaneously the cities of Duluth, Superior, Ishpeming, Ashland, Marquette, and Iron Mountain have grown to importance, and the regions of the Red Valley and of Lake Erie have also gained large populations.

As we have indicated, the United States and Canadian Governments have constructed independent canals adjacent to the falls. A Sault Sainte-Marie exists on each side of the rapids; the American canal is on the south side and the Canadian canal on the north. The two Governments

have spent only a few millions sterling upon these telling economic operations. The two nations concerned, it is not too much to say, are reaping hundreds per cent. per annum upon the outlay, not in the form of direct dividends upon capital, but in trade and industry actually created by a combination of engineering and statesmanship.

What the canals at Sault Sainte-Marie do for Lake Superior and Lake Huron, the Welland Canal does for Lake Erie and Lake Ontario. At a cost of about seven million pounds these two lakes have been connected by a waterway twenty-seven miles long. The Sault Sainte-Marie and Welland Canals are the two main links in a complete chain of ship canals which connect Lake Superior with the mouth of the St. Lawrence River. In all, some twenty-five miles of artificial navigation have joined up the Great Lakes and the St. Lawrence, at a cost which, although actually great, is negligible either in relation to the finances of the countries concerned or to the results achieved. It may give a conception of the magnitude of the trade created when we say that the traffic through the two St. Mary's Fall Canals is much greater in volume, if less in value, than that which passes the Suez Canal.

The Stimulating Effects on Holland of Connected Waterways

In the Old World we find that Holland owes much to the engineer. The great North Sea Canal, fifteen and a half miles long, was opened for use in 1876, and its effect was remarkable and instantaneous. For twenty years previously the trade of Amsterdam had been stagnant, while Rotterdam had grown greatly in wealth. Within six years of the opening of the "Noordzee" Canal the tonnage entering and leaving at Amsterdam doubled, and has since grown further, although not at so great a rate. In many other ways Holland has profited by internal navigation. She has added to her excellent rivers a network of artificial waterways which greatly exceed her railways in mileage. There are two hundred and sixty-five canals, with a total length of 2100 miles, in this tiny land. A considerable proportion of the whole is controlled either by the State or local authorities, and navigation upon these public waterways is free of tolls. Holland, of course, has a special need of canals for drainage purposes, but it is impossible not to admire the thorough manner in which this actually poor country has sustained her people by the development of internal navigations.

The Merwede Canal connects Amsterdam with Utrecht and the Rhine, and Rotterdam is also connected up with the German ports of the Rhine. The boats using the Merwede Canal are 280 to 330 feet long, and vary in draught from $7\frac{1}{4}$ to $8\frac{1}{2}$ feet. According to their draught, they are permitted to travel at speeds varying from $4\frac{3}{4}$ to $7\frac{1}{2}$ miles an hour.

The Marketing of Garden Produce in Holland by Water Carriage

When the Royal Commission on Canals visited the canals of the Westland, they were greatly struck by the market gardening developments due to the wise use of water carriage. A produce worth five hundred thousand pounds a year depends on the Dutch artificial navigations, and is growing so rapidly that the canal system is being enlarged. The produce is brought to market on the canal itself, the auction hall being conveniently built across the waterway, so that the laden boat comes into the hall at one end, and passes out at the other on to its destination after its contents have been sold by auction without cost or trouble of removal from the vessel. The economy and speed of the process will be apparent.

From Holland, a land which has a peculiar dependence on the wise handling of water navigation, we pass to other European countries where canals play an exceedingly important, if not so decisive, a part, and the conditions of which render them more instructive from the British point of view. Very full information is available on the subject, both in foreign reports and in the valuable papers published by the last Canal Commission.

The Lessons Offered to Britain by France, Holland, Belgium, and Germany

The French inland navigations are of much importance and interest. There is a good deal of resemblance between the conditions in some parts of France and the United Kingdom, although, of course, there are no two countries of Europe the conditions of which with regard to internal traffic may be said to be precisely similar. We shall do well, however, to bear in mind, in considering Continental experience, that there is at least as much difference between France and Holland, or between France and Germany, in respect of canal conditions, as there is between any one of these countries and the United Kingdom. It would be a great mistake, therefore, to put aside Continental experience, and not to give great

weight to the fact that in France, Belgium, Holland, and Germany alike canal systems are highly developed, and in process of constant improvement and extension.

In France, as in England, canals preceded railways; and in the one country, as in the other, the advent of the railways was a setback to the development of the waterways. French railway construction began in 1835. In 1851 the smaller French railways began to amalgamate, and by 1857 90 per cent. of the French railways were owned by six great companies—the Nord, the Est, the Ouest, the Paris-Lyon-Méditerranée, and the Midi. France very wisely did not give unlimited concessions to railway speculators, but retained the right to resume ownership. Indeed, about the middle of the twentieth century (between 1950 and 1960) the whole of the French railways will become the property of the French State without compensation. It is hardly necessary to add that the French Government will then come into a magnificent revenue, which will have an extraordinary effect upon the finances and national strength.

With the growth of the French railway system the traffic of the French waterways declined, as it declined here, but in 1879 a law was passed to bring about a general reorganisation of the entire traffic problem including seaports, railways, and waterways. As a consequence, between 1879 and 1900 the French Government, with magnificent foresight, expended £11,200,000 upon improving river navigations, and £14,600,000 upon the construction of new canals and the improvement of old ones.

The new policy made an entire change in the French traffic position. The general conception of the law of 1879 was to standardise the entire waterway system in main and branch lines, to abolish all tolls and dues, and to repurchase outstanding concessions of waterways which had been made to *entrepreneurs*. At the present time nearly the whole of the French inland waterways are owned by the State.

All important lines are now standardised for the navigation of canal-boats of 300 tons burden. The measurements of these large canal vessels should be noted: length, 125 feet, beam 16·4 feet, and draught 5·9 feet. It is a striking contrast to the tiny vessels which navigate our waterways.

The great change effected by the 1879 law will be realised from the following particulars showing the length of French waterways capable of carrying these 300-ton boats in 1878 and 1905 respectively:

IMPROVEMENT OF FRENCH WATERWAYS

Canals Capable of Carrying Boats of 300 Tons Burden

	Canals	Canalised Rivers	Total
	Miles	Miles	Miles
1878	618	287	905
1905	1,306	1,671	2,977
Addition in 27 years ..	788	1,384	2,072

It will be seen that the French canal system has been not so much improved as re-created in the last quarter of a century. The French canal system in 1878 was poor and inefficient. The French canal system of today is adequate and highly efficient. Before 1879 the majority of the French waterways could carry boats of no greater capacity than about one hundred and fifty tons. It should be noticed that the navigable rivers received much attention, in addition to the construction and improvement of canals. As a consequence, the total traffic of the French waterways has increased very rapidly since 1880.

INCREASE OF FRENCH CANAL TRAFFIC

	Tons Carried		Tons Carried
1880	18,000	1900	32,400
1885	19,000	1905	34,000
1890	24,200	1906	34,100
1895	27,200		

It is also remarkable that, during the period referred to in this table, canal traffic has grown much more rapidly than railway traffic in France, although the latter has increased considerably. The water traffic nearly doubled in the period under review, a period, be it obserevd, in which the traffic on British canals *remained almost stationary*.

The canal is peculiarly suited to the carriage of heavy and bulky goods, such as coal, building materials, road materials, agricultural produce, timber, and raw materials in general. Of the goods carried on the French inland navigations about 30 per cent. consist of coal, about 36 per cent. of building and road materials, and about 13 per cent. of agricultural produce.

As has already been pointed out, all tolls and dues have been abolished on the French canal system, and merely the cost of freight has to be borne by French traders. The freight costs come out very low indeed, as

may be gathered from a few examples. The carriage of coal from Dinan, on the Escaut, to Ris, on the Seine, above Paris, a distance of 219 miles, costs only 3s. 7¼d. per ton. The carriage of paving-stones from the Seine above Paris to Roubaix, a distance of 268 miles, costs 2s. 4d. per ton. As no tolls are paid, it may be said that the French Government subsidise the traffic, but the amount of the subsidy has been calculated by Mr. W. H. Lindley, M.I.C.E., to whom the Canal Commission were indebted for a most valuable report on Continental waterways, to be only 0·21 pence per ton-mile.

We have said that the canals, as improved under the law of 1879, are toll-free. In 1903 another French canal law was passed, providing for a further considerable expenditure, and it was enacted that, in regard to new canals, small tolls should be charged, in order that the cost of canal maintenance should be in part made by those who directly use them. It may fairly be said that, when we consider the figures quoted, and the further fact that after experience of the law of 1879, and its great expenditure, the French Government in 1903 passed a new law providing for a further State expenditure of over £8,000,000, the French people are fully satisfied with what the canal system has accomplished for French national economy.

The Belgians also have spent much State money upon waterways, and, like the French, they are so fully satisfied with the fructification of their expenditure that they are continually enlarging and improving their waterway system. The Belgian Government owns virtually the entire railway and inland waterway systems of the nation, and in pursuance of a general policy has spent money lavishly on the seaports. The wonderful progress of Antwerp is a monument to the wisdom of this policy.

The Belgian waterways, including canals and canalised rivers, have a total length of 1345 miles. The waterway traffic is subject to light tolls, which, small as they are, are sufficient almost to meet the cost of maintenance and current improvements. Direct monetary profit could be obtained if it were thought wise, but it is not thought wise. Belgium looks for her profit in the general increase of the trade of the country, which, of course, is far more important than using a canal system for revenue-production.

The statement at the foot of this page shows the growth of the goods traffic on the railways and waterways of Belgium.

The waterway traffic has increased by 120 per cent., while the railway traffic has increased 60 per cent. Both figures are eminently satisfactory, but the increase of the waterway traffic in only seventeen years is very striking.

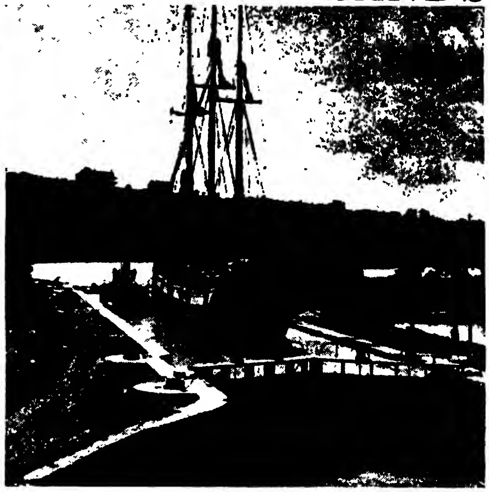
These facts should be eloquent for the people of the United Kingdom, whose waterway traffic has been stationary for so many years. The circumstances of Belgium and of England are to a large extent comparable in the matter of waterways. Both have mines and industrial centres which need connection with great ports. Let us compare Birmingham with Liége, which has sometimes been called the Belgian Birmingham. Liége, by means of the waterways, can send a cargo of minerals ninety-five miles, from Antwerp to Liége, at a total cost of freight, plus canal dues, of only 2s. 4¾d. per ton, or about one-third of a penny per ton-mile. A cargo of steel rails can be sent from Liége to Antwerp for export at about the same rate, and the goods can be taken from or to the side of the ship at Antwerp in the same canal-boat which carries them to or from Liége. Birmingham is about the same distance from Bristol or Liverpool as Liége is from Antwerp. To convey the same goods between Birmingham and Liverpool or Bristol would cost about three times as much as the cost of transport between Liége and Antwerp, and of course transhipment would be necessary at the port. Such are the hard

THE LENGTH AND TONNAGE OF THE CANALS AND RAILWAYS OF BELGIUM

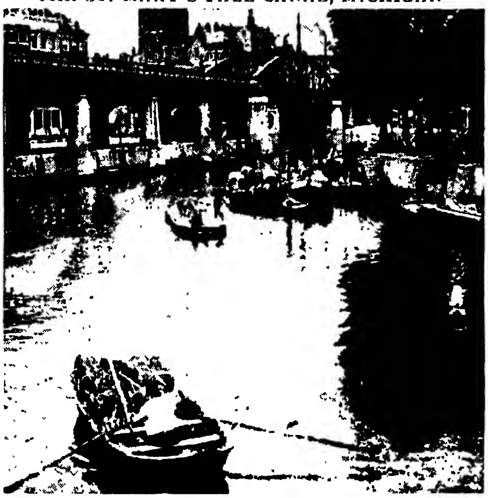
Year	CANALS		RAILWAYS	
	Length	Tonnage	Length	Tonnage
	Miles		Miles	
1888	998	24,800,000	2,365	40,300,000
1890	1,018	25,200,000	2,378	43,000,000
1895	1,010	30,200,000	2,408	46,700,000
1900	1,016	38,200,000	2,881	55,100,000
1905	1,016	53,300,000	2,874	65,300,000

INLAND WATERWAYS OF OTHER LANDS

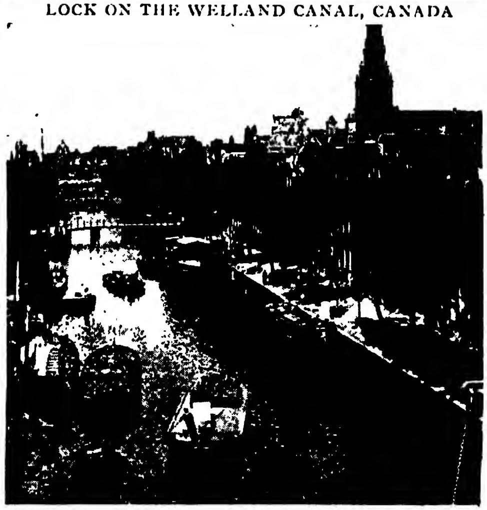
THE ST. MARY'S FALL CANAL, MICHIGAN



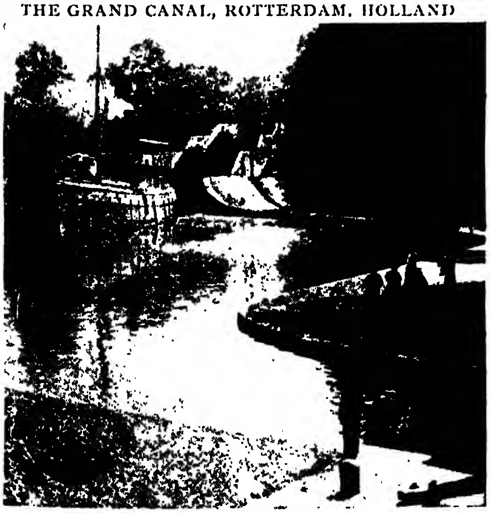
LOCK ON THE WELLAND CANAL, CANADA



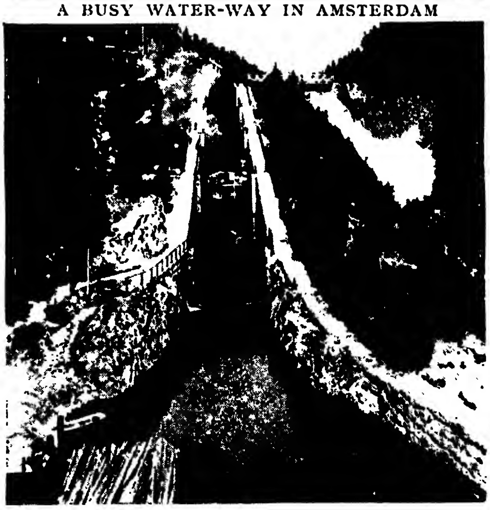
THE GRAND CANAL, ROTTERDAM, HOLLAND



A BUSY WATER-WAY IN AMSTERDAM



THE GÖTA CANAL TRÖLLHÄTTAN, SWEDEN



LOCKS IN BANDAK NORDSJÖ CANAL, NORWAY

facts vouched for by the Report of the Canal Commission and it is not a little astonishing that British traders are content that they should remain at such a disadvantage.

In 1904, Sir Cecil Hertslet reported to the Foreign Office in a consular report on the subject we are considering. He remarked: "This gradual but steady growth of a uniform canal system, intended for and serving as an auxiliary to the railways, which are also for the most part under State control, has rendered transport as cheap as possible, and by this means the Belgian manufacturer has been enabled to compete on most advantageous terms with his foreign rivals. . . . The result of this policy is that goods can be sent, in many instances in barges of 300 tons carrying capacity, direct from the factory to the seaport or other place of destination without transhipment. The producer, thus saved the expense incurred by such transhipments, finds himself in the position of being able to make a profit greater by this amount, or to underbid those of his foreign rivals who may not enjoy such peculiar advantages. This remark applies in a double sense, for a gain is made on the transport of the raw material as well as on that of the finished article."

It cannot too clearly be remembered that transport is the very life of commerce, and that we cannot afford to forgo advantages which we could so easily enjoy in common with the Belgians.

The German inland navigations are mainly based upon the magnificent rivers which traverse German territory; and it is therefore very difficult to make any true comparison between German and British conditions in this respect. Nearly one-third of the entire length of the chief waterways of Germany consists of the more important navigable free rivers, which have a length of nearly 2000 miles. Thus the seven longest free rivers, as far as they lie within the German boundaries, are as follow.

	Length
The Rhine, from Strasburg to the Dutch frontier	355 miles.
The Main, from Bischberg to Offenbach	217 "
The Weser, from Münden to Bremen	227 "
The Elbe, from Saxon-Austrian frontier to Hamburg	386 "
The Oder, from the junction with the Neisse to Stettin	349 "
The Vistula, from the Russian frontier to Danzig	153 "
The Danube, from Kehlheim to the Austrian frontier	120 "

These seven natural navigations carry over 80 per cent. of the inland waterway traffic of the German Empire.

But while Germany is favoured with fine rivers which in part compensate her for her lack of seaboard, we must not suppose that the Germans have been content with their natural waterways. Large sums have been spent upon the improvement of the river navigations, and the great commercial cities have co-operated. Take, for example, the Main. When the Prussian Government canalised this river, the city of Frankfort spent £450,000 upon a commercial harbour. This is only one instance out of many that might be quoted to exhibit the spirit in which German public works have been generously carried out by civic authorities in the public interest.

The Germans have constructed 425 miles of minor canalised rivers and 900 miles of canals. One of the most important of the great artificial waterways is the Dortmund-Ems Canal, which links the Westphalian coal and iron district with the canalised River Ems, and so with the port of Emden. Eventually this canal will join the Rhine to the River Weser and the city of Hanover.

As in Belgium, both the waterways and railways are State property, and the municipal authorities have everywhere co-operated by constructing harbours and wharves for the accommodation of canal traffic. We need not be surprised to learn that all along the fine waterways German manufacturing firms have established themselves to take advantage of the remarkably low cost of transporting materials by water. In 1904 an official Prussian report on the waterways stated that: "In conjunction with the railways, the navigable waterways exercise a special attraction on industries, and more so than the railways alone have done; therefore the waterways, on account of the qualities peculiar to them, appear to have a strong decentralising influence."

The kingdom of Prussia alone has spent over £27,000,000 in constructing and improving the national waterways. No dues are charged on the great rivers, and those charged on the canals and canalised rivers are very low. They are calculated to cover a part only of the cost of maintenance, the conception being exactly the same as in Holland, France, and Belgium—that it is the duty of the nation not to use the waterways as revenue-producers, but to make them as nearly as possible free and open roads upon which the nation may advance to an increasing degree of trade prosperity.

Mr. W. H. Lindley, in his official report on the German waterways, brought out some remarkable facts with regard to the progress of German water traffic. The year 1885 may be taken as that of the beginning of the improvement of the Prussian inland navigations. Between that year and 1905, German water traffic increased threefold. Between 1875 and 1905 the actual tonnage increased from 13,600,000 tons to 67,000,000 tons.

The Remarkable Increase and Prospect of Increase in German Canal Traffic

One or two specific instances may be quoted. On the Dortmund-Ems Canal the traffic rose from 476,000 tons in the first year, 1900, to 1,731,000 tons in 1906. In 1875 the tonnage received at Hamburg inland by the Elbe was only 799,000 tons. The river was then improved, and by 1905 the tonnage had risen to 7,800,000 tons. And this in spite of the fact that the railway traffic under the same fostering national care had increased hand over hand. In the twenty years 1885–1905, water traffic increased threefold, and railway traffic two and a half times.

From what has been said, it will be understood how national railways and national waterways dovetail into each other in a national transport system. In Germany, as elsewhere, water-borne goods are chiefly those which have large bulk and weight in proportion to their value. To relieve the railways of a large proportion of this class of traffic is, of course, to economise the railway system. It remains to add that, as in the case of the other countries reviewed, the German authorities are projecting even greater canal works. In the course of not many years the great rivers of Germany will be connected up by a magnificent series of artificial waterways capable of accommodating boats of heavy burden. In 1905 the Prussian Government enacted a law sanctioning new canal works estimated to cost nearly £17,000,000, and already further great waterways are projected.

British Stagnation, Notwithstanding Proofs of Prosperity Following Canal Enterprise

Enough has been said to show what a great part is played in the economy of Continental nations by the combination of rail with water transport, the canals not so much competing with the railways as complementing them in respect of heavy traffic.

We now come to the case of the United Kingdom, and unfortunately we find that during the last thirty years or so, during which France and Germany have spent so many millions in improving their internal communications, the traffic of British canals has remained stationary, and has greatly declined in proportion to the entire traffic of the country. Only one great canal undertaking has been carried out, and that is the Manchester Ship Canal, the completion of which reflects the very greatest credit upon the city of Manchester. The Manchester Ship Canal would probably never have been completed if the Corporation of Manchester had not had the wisdom and courage to lend £5,000,000 to the undertakers when no more could be obtained privately. The effect of the canal upon the prosperity of Manchester has been marked. Manchester had apparently come to a standstill, and her land values were declining. After the opening of the canal, a great change was witnessed. The rateable value of the town began to rise rapidly, and, judged by every test, Manchester has been repaid many times over for her enterprise. Some other isolated instances of British canal improvement may be quoted, such as the new works on the Aire and Calder and Weaver Navigations, and the Leeds and Liverpool and Grand Junction Canals.

The Canal Commission's Summary of the Causes of British Canal Paralysis

Unfortunately, these are exceptional instances, which serve but to emphasise the general case, which is that for the last two generations our canals have, at the best, been at a standstill, and, at the worst, been decadent. Private capital cannot be obtained for canal work, for reasons which the Canal Commission thus summarised:

(1) The haphazard system by which canals were originally constructed, without any uniformity of gauge or locks, and their ownership by so many different authorities and companies; and the arrest of development and amalgamation in consequence of the advent of railways;

(2) The situation which has been caused by the transfer of many important sections of the waterways to railway companies;

(3) The paralysis or arrest of development which has resulted from all these causes throughout the whole canal system.

Thus, as the Commissioners point out, because the canal authorities are weak, divided, and unorganised, they cannot raise capital to improve the navigations; and because the canals cannot be improved, the canal authorities find no favour with the investing public. It is an incredible position of deadlock, to apply a word which might almost have been coined for the

special purpose of describing the unfortunate and peculiar condition of our canal system. Here, as in France and elsewhere, the waterways fell into disfavour before the all-conquering locomotive. Here, unfortunately, as not elsewhere, there was no recovery from the shock. Other nations have solved the problem by bringing State powers to bear where private powers failed, and we have seen how brilliantly they have succeeded in every case. Here we are not only content that the railways should remain private powers, but we have allowed them to control sections of the canals and thus to strangle the British waterways system.

How difficult it is to use British canals as they are at present managed will be gathered from the following instance given by a leading member of the Worcester Chamber of Commerce:

"A local firm of timber merchants purchases its props from the great larch-woods in the neighbourhood of Stroud, and sells them to the South Staffordshire mines; to take them there by water would involve passage over seven different navigations—the Stroudwater Canal, the Berkeley Canal, the Severn, the Staffordshire and Worcestershire Canal, the Stourbridge Canal, the Stourbridge Junction Canal, belonging to the Great Western, and the Birmingham Canal Navigation to end up with. Now, to take a load of wood over these seven different canals would mean not quite as many different bookings, as there are one or two combinations, but that would mean five different bookings; it would mean five different declarations of cargo, and it would mean entrusting the money for five different sets of tolls to the man on the boat. There is great disadvantage in that."

Moreover, our navigations are of different dimensions, and in many cases only accommodate toy barges; the fine 300-ton canal-boats of the Continent would be useless on the British canal system.

Faced with the serious problem thus broadly outlined, the Canal Commission made some bold recommendations to Parliament. They recommended that, as the first step in any comprehensive scheme of British waterway development, it would be desirable to convert into great and practicable canals the heterogeneous waterways which connect up the Midlands with the estuaries of the Thames, Mersey, Severn, and Humber. These main lines would form roughly a cross. This important suggestion, which it is not too much to say would galvanise not only the trade of the Midlands, but trade and industry all along the routes of the canals, is shown clearly on the map on page 2321, which is specially commended to the reader's attention. The numerals on the map refer to the four main routes, which are further outlined below.

PROPOSED NATIONAL CANAL SYSTEM.

(The Route numerals refer to the map on page 2321)

	Miles
ROUTE "A": Midlands to London:	
Main Line—Birmingham to London ..	128·80
Branches—Leicester to Norton Junction	32·34
Bull's Bridge to Paddington	13·25
Total "A"	174·39
ROUTE "B": Midlands to the Humber:	
Main Line—Leicester to Nottingham	33·42
Nottingham to Humber	76·48
Branch—Fradley Junction to Trent Junction	28·23
Total "B"	138·13
ROUTE "C": Midlands to the Mersey:	
Main Line—Birmingham to Northwich	79·52
Northwich to Mersey ..	14·14
Branch—Wolverhampton to Haywood Junction	19·60
Total "C"	113·26
ROUTE "D": Midlands to Bristol Channel:	
Main Line—Birmingham to Hawford Junction	26·21
Hawford Junction to Worcester	4·49
Worcester to Gloucester ..	28·90
Gloucester to Sharpness ..	16·46
Branches—Wolverhampton to Stourport	23·54
Stourport to Hawford Junction	32·00
Total "D"	108·06
GRAND TOTAL OF MILES	533·84

The suggestion is thus that over 500 miles of waterway should be converted into great highways intersecting in the Midlands. Great manufacturing centres would be linked up with the ports by a system affording transport which, for heavy articles, would in many cases be only one-third to one-half the cost of railway freight. Importation, exportation, home trade, and shipping would alike benefit; and from the Midlands outwards to the ports of Hull, Liverpool, London, and Bristol, England would undoubtedly repeat the experience of Continental nations in witnessing an enormous growth of traffic.

It would, of course, be necessary to make the waterways large enough to accommodate canal-boats of considerable draught. It is

cheaper to build one 300-ton boat than three boats of 100 tons each; it is just as obviously cheaper to actuate one 300-ton boat than three boats of 100 tons each. Not only ought the plan to be carried out, but tc be carried out on such a proper scale as has marked the canal policy of France or Belgium. We have a vast amount of foreign experience to guide us, and we are in the position of adapting that experience to meet our own special needs.

The carrying out of such a scheme, the dimensions of which would justify the use of the term "national," would obviously be considerable. According to estimates made by Sir John Wolfe Barry and Partners, to carry out the great connected plan indicated in the map on this page would cost about twenty-five million pounds if the navigations were of sufficient dimensions to accommodate canal-boats of the Continental pattern, of about three hundred tons capacity; and this figure is exclusive of the cost of water supply and other incidental expenditure. In short, the suggestion is that we should undertake canal works on a Continental scale. They are works truly of great magnitude and considerable cost, but these are considerations which, as we have seen, have not dismayed the statesmen of the Continent. On the contrary, after having made such expenditures, we see them contemplating the enormous benefits derived, and proceeding to enlarge their canal systems still further. Even as this article is going to press (1912), news comes from Germany of the getting out of plans for another Rhine canal project estimated to cost £11,500,000, in addition to the great projects of which we have already spoken.

THE GREAT NATIONAL CANAL IMPROVEMENT OUTLINED BY THE ROYAL COMMISSION OF 1909

We are face to face with a problem in which we have either as a nation to risk a certain amount of capital on a great and most promising national object, or be content to see our waterways remain largely derelict, since private enterprise cannot, as we have seen, help us. The worst outcome of the experiment would be the sinking of such a sum as that mentioned for no return, except the monetary stimulation of trade and employment caused by the works of construction. If that were the end, we should only have risked a sum of money barely more than half of what we spend annually upon the Navy, or the cost, to put it in another way, of a war of a very trifling character indeed. It would be as though each of the inhabitants of the United Kingdom had sunk about ten shillings. Looked at this way, we see the large-scale improvement of our waterways as a matter which, although actually great, is trifling relatively to our population, our income, and our resources. We have to weigh this most unlikely worst possible against the probability that what has done so much for Continental nations could not fail to do much for the United Kingdom also.

WAR FOUGHT ON THE HEARTHSTONE

"ON STRIKE," BY SIR HUBERT VON HERKOMER, R.A., C.V.O., IN THE DIPLOMA GALLERY
Reproduced by permission of the artist and the President and Council of the Royal Academy

THE REVOLT OF LABOUR

Why Great Britain Has Become the Storm-Centre of the World of Industry

ANARCHISM VERSUS SOCIAL REFORM

In the winter of 1911-12 the whole civilised world was startled by an explosion of the social forces of our country. It was the most unexpected event of modern times. There had, it is true, been a period when the British race was regarded as the most unstable, violent, and destructive people in Christendom. But this period had faded into the background of history It was only students of Bossuet and other great foreign writers of the seventeenth century who were aware that, at the beginning of the modern era, our country was generally regarded as the danger-centre of civilisation. The fact is, our race managed to master the forces of revolution that it created. And so well was the work of resettlement carried out that for two hundred years our country stood like a tower high above the seas of change that swept over Europe, and beat against the fabric of the most ancient and remote civilisations of Asia.

Foreign thinkers, perplexed by the forces of unrest working in the mind and life and government of their own peoples, gazed with envying admiration at the solid and broad-based organisation of British society. In innumerable studies of our social, political and industrial life, they endeavoured to discover the secret of our extraordinary national stability. It is now about fifty years since they began to agree among themselves that the British race mainly owed its stability to a kind of happy stupidity, which made it quite impervious to the new ideas agitating the minds of other nations. We were supposed to be so immersed in the practical, personal side of business affairs that we had neither the time nor the inclination to think over the larger issues of modern human society. Engrossed in the task of exploiting our material resources, we went on increasing in strength and wealth, leaving to France and Germany the task of solving some of the most important new social problems. Such was the common foreign view of the matter; it obtained among both the revolutionary and the conservative schools of European thought.

A considerable number of European thinkers admired the results of our apparent inertness of mind. The British race, they said, is working out its salvation in its own way. It relies wholly on the knowledge born of experience, and it is averse from making large and sudden changes, not because it cannot think out ideas, but because it likes to walk slowly but firmly on a solid causeway of facts that it gathers and builds together as it goes along. This was the view taken by Taine, one of the leaders of modern French thought, and it was generally adopted by the conservative school throughout Europe. On the other hand, the leaders of the various revolutionary movements on the Continent professed themselves to be disgusted with the selfishness of the British trade unionists. Our organised working classes were contemned for their supposed indifference to the general welfare of human society. "They fight only for higher wages for themselves," said foreign revolutionaries, "and they have no thought for the solidarity of the interests of labour throughout the world!" Several famous missionaries of Socialism, who came to our benighted country to preach the new gospel of class warfare, admitted that they were unable to excite any interest or enthusiasm in the average British workman.

Now, however, even the wildest of foreign revolutionaries is amazed at the volcanic outburst of social unrest that has occurred in Great Britain. Schemes of general cessation of work, that no foreign syndicalist has found practical in his own country, have suddenly been carried out by British railway-men and British colliers.

In less than a year our country was transformed from the grand centre of social peace into the main centre of social strife. In the nineteenth century France was the source of most of the chief movements of far-reaching change. As she swung from Democracy to Imperialism, and from Imperialism to Communism, she radiated influences that variously affected the nations around her. Indeed, she wasted a good deal of her vital strength in violent oscillations of thought and action that set up movements in European life from which she benefited less than some of her neighbours. In Germany, for instance, the spirit of French Imperialism received its complete development at the hands of Bismarck, while the spirit of French Socialism was cast into a strong and practical form by Karl Marx and other men of his school. Practically every movement that modern France has started has been carried out by another nation. And at first glance it looks as though the latest upheaval among our working classes is of French origin.

The New Form of Anarchism that has Sprung up in France under the Name Syndicalism

A few years ago some French revolutionary leaders conceived a new plan of action. Perhaps they saw that ordinary Socialism could be reduced to practice by a despotic Government, in a more thorough way than a democratic State could carry out the proposed reorganisation of society. And, as a fact, the military empire of Germany was then much more Socialistic than was either France or Great Britain, though our country was cautiously advancing towards a fairly large bureaucratic control of the lives of the people. "We are all Socialists now," Sir William Vernon Harcourt said; and his hearers felt the truth of it. The fact was that the governing classes of some of the chief European countries saw that Socialism could be easily converted into an improved form of the fatherly kind of State control which had obtained in Great Britain and elsewhere at the middle of the eighteenth century.

This was not what the French Communists desired. So they abandoned all the ordinary ideas of the thinkers of the old Socialistic school, and invented the new policy of syndicalism. Syndicalism gets its name from its plan of welding all syndicates or trade unions into a general labour confederation. This new confederation does not aim at advancing the interests of the working classes by sending representatives to Parliament to take part in the making or altering of laws. It wants no share of power whatever in any present form of government, because it intends to destroy completely the organisation of modern society. The syndicalist hates and fears the State. He is afraid it might find a place for his movement, and reduce all the machinery of the confederation into a branch of a Socialistic bureaucracy. His aim to is paralyse the State by a general strike, destroy the existing form of social organisation, and build on the ruins a Utopia for the manual labouring classes. It was because modern Socialism was attracting the middle classes that Fernand Pelloutier gave it up, and founded the narrower policy of trade union revolution Syndicalism is avowed class warfare.

The Supposed but Unproved Influence of Syndicalism on the British Workman

Introduced into Great Britain, syndicalism is credited, by a gross exaggeration, with having produced an explosion of unrest such as the leaders of the French Confederation of Labour cannot hope to accomplish for many years. In any case, Great Britain is now the danger-centre of the civilised world; and we already have the extraordinary spectacle of the movements of British workers producing, by the contagion of example, great labour troubles in Germany and America. So it seems that, for good or for evil, Great Britain has again become the social laboratory of the civilised world.

For our part, however, we incline to the opinion that the French syndicalists and their English disciples have had little real influence in bringing about the present condition of things. Indeed, the advertised syndicalist is only a fly on a very large wheel driven by economic forces which have slowly been developing in our country.

The Suffering of English Workmen Under the Changes of the Modern Industrial Revolution

Was it not Froissart, in the fourteenth century, who said that the English people were the most patient in the world, but that they were more violent than any others in the end? Well, we have not lost the quality of patience which surprised the Flemish chronicler; and if our final outburst takes a less violent form than it did of old, it may be none the less effectual. For some generations a considerable portion of our people have been suffering terribly from the results of the modern industrial revolution. A genius for mechanical invention has suddenly been elicited, from men of all classes, which has had the result of displacing a large amount of human labour.

In many branches of industry there has been revolution after revolution. The fruit of long training, and the skill handed down from father to son, have been rendered practically valueless by the creation of new machinery and new methods of organisation.

Much of the strange stillness that fell on our national life about the middle of the nineteenth century, and excited the wonder of foreign critics, was not the quietude of a contented people, but the intense stillness of a bitter struggle for the means of livelihood.

The Internal Strife Caused by the Development of New Methods of Industry

It was a struggle for individual efficiency between the members of a disorganised army of craftsmen. Having lost their old tools, they were fighting among themselves for the possession of the fresh instruments of work provided for them by a new race of inventors. In effect, it was a contest in the capacity for being educated in strange methods and strange ideas ; and, as a rule, the men with the quickest minds and the best opportunities won. After their triumph over their fellow-labourers, they often found themselves at odds with their employers. So they organised themselves for victory as soon as they regained the right of combination, and then, by means of their trade unions, they forced up their wages until they became the best-paid workmen in Europe. It is only fair to add that they thoroughly deserved the rate of wages they won. For, in intelligence and manual skill, there is not their like in the world. It has recently been stated on high authority that it takes eleven men in America to do the work of ten in England. And the skilled German mechanic also lags behind our men. The English workman is a picked man—picked after the fiercest and longest competition in history.

The Effects of Trade Union Organisation on the Position of the More Skilled Workmen

After their long struggle for social efficiency in the new world created by the modern inventor, our best artisans found themselves in a fairly happy and comfortable position. Though they sent representatives to Parliament to look after their position, they did not rely entirely on this constitutional means of improving their lot. For they possessed, in their trade unions, a magnificent system of organisation which enabled them to engage in private warfare with their employers. And it was chiefly by means of strikes and the threat of strikes that they captured a somewhat larger share of the profits of the industries on which they were engaged. The division, such as it is, has not been obtained by any system of State control, but simply by giving to the workers the right to combine and strike, and to the employers the right to combine and lock out.

In short, the struggle has been conducted in a fierce and yet equal manner in accordance with a system of free industrial institutions. It was by liberalising the conditions of this long and intense industrial strife that there was maintained that appearance of national stability and national solidity which made foreign observers think we were a race without any causes or symptoms of social unrest. Our skilled working men marched forward with a clear and steady aim. They wanted more wages and more time for recreation; and, instead of trying to get these things by overturning the Government or dreaming of a Utopia, they fought first for the right to combine, and, winning this, they struck at their masters until, in some cases, the masters had to show by their books that they could not increase the pay of the men without running their businesses at a loss, Then came in the British invention, the sliding scale of wages. By means of it workmen obtained some of the benefits of co-partnership, without the disadvantages.

The Position of the Workmen of Low Industrial Efficiency Outside Trade Organisations

But the dock strike engineered by Mr. John Burns showed that modern trade unionism was not a complete solution of all the social problems created by the inventiveness of our race. Owing either to lack of opportunity or to want of intelligent adaptiveness, about a third of our population had failed to survive the effect of industrial revolution. Far from profiting by the new inventions and the new social organisations of the age, and lifting themselves up to a position of comfort unknown to their forefathers, a deplorable number of our people had fallen so low in industrial efficiency as to be unable to earn the food they required. Most of them lived on the poverty line, just managing to exist, but often harming their constitutions, and handing on their enfeebled bodily powers to their children. In addition, there was, especially in the cities, a large residuum of permanently pauper people.

If the new movement of syndicalism made for the progress of industrial organisation among the lower labouring classes that have hitherto been unable to combine in trade unions, the danger of a revolution

might be worth running. For we do not think the danger would be great. It will be remembered that the present Labour Party was at first supported by a vast army of trade unionists, who were excited by the hope of establishing a social millennium. Probably without this hope the organisation of the party would not have been effectively carried out. It, however, seems that many working men are satisfied for the time being with the moderate rate of progress achieved by the Government ; and the consequence is that the Labour Party has ceased to grow in political influence.

The Danger to Society of the Existence of a Large Population Left in Bitter Want

If the syndicalists were able to organise a considerable number of the lower-class labourers, there might be a return to the earlier condition of things. Very likely strikes would become more frequent and wider in action. During the new period of industrial warfare the nation would be seriously inconvenienced ; and now and then matters might look dangerous. But when a fairly general rise in wages had been won, the social structure would recover its strength and stability.

There can be little doubt that the working classes of the whole civilised world will continue for some years in a state of great unrest. Our country will probably remain the storm-centre, owing to the fact that an exceptional proportion of our population is in a condition of bitter want. But the extraordinary feature of the affair is that this outburst of discontent has occurred at a time when the country generally is enjoying a remarkable prosperity. In 1900 our exports were £291,000,000 ; in 1910 they had increased to £430,000,000. Yet it is in this period of marvellous expansion of our industrial activities that the strange new forces of Anarchy have worked up to flash-point.

The Cheapness of Money Giving Less Pay for More Valuable Work

A year ago our chief port—the centre of the world's commerce—was held up for ten days ; our second port, Liverpool, was in a state of siege. Disorder spread from Southampton to Glasgow. and from Hull to Cardiff ; our railway system was partially paralysed, and the transport trade of North-Eastern England was shut down. Our nation suddenly fell from a position of glorious prosperity into the danger of a general famine. Some months afterwards the entire fabric of our industries reeled under the shock of the great coal strike.

The immediate cause of this widespread disturbance is well known. There has been a universal rise in the cost of living, and wages have not advanced in proportion. As there is every likelihood of the cost of living increasing, both our organised working classes and our lower order of labourers will have either to struggle for more money or sink into a position of hardship or misery. The vast multitude that is already shut off by the gates of poverty from the comforts of civilised life will not be soothed by learning the reason for the increased cost of the necessities of existence. It is reckoned that £750,000,000 worth of gold has been won from the earth in the first ten years of the twentieth century. As gold is still the measure of value, money has become cheap, and the food that is bought by money has become dear. This does not matter to the comparatively few persons who are profiting by the output of the gold-mines.

But every wage-earner of any kind in the world is now doing more valuable work and receiving less of the necessities of life in payment for his labour. His work is worth more than it used to be, owing to the cheapness of money ; but as he still receives wages calculated on the old basis, he has to go into the market and buy the things he wants at an increased cost.

Is Wealth Now Becoming a Source of National Decay, as was Once the Case with Spain ?

A similar thing happened in Spain during the exploitation of Peru and Mexico. Gold became abundant and cheap, and the few persons who obtained the gold were lapped in luxury. Gold was then the medium of exchange as well as the measure of value ; and the cheapness with which a man could be paid for real productive labour was so disastrous that Spain has not yet recovered from the misery, apathy, and confusion into which her working classes fell. The cheapness of gold could only have been balanced by a high general rise in the standard of wages. As the working classes were not organised for the industrial warfare necessary in forcing up the remuneration of labour, and as the State was utterly blind to the cause of the misery of the common people, and therefore took no steps to remedy that misery, the mighty empire of Spain fell under the weight of the golden treasures extorted from the American natives.

Great Britain has won her wealth by fairer means than the Spanish adventurers won theirs, but, nevertheless, that wealth has

become a source of national decay. We are paying our working classes in a depreciated currency. Nominally, our farm labourers receive 17s. 6d. a week, but actually the money that is put into their hands is not worth what it was ten years ago. It will not buy the same amount of food and clothing. So it is with the workers in every branch of our national activities. Their wages have diminished in value, and at the same time the means of luxury of the wealthiest classes have enormously increased. The clerk, the mechanic, the labourer, see all around them signs of a marvellous prosperity, but in their own homes they find the means of comfort diminishing, though the money brought home every week is perhaps just a little more than was earned ten years ago. hitherto been too poor and too feeble to profit by trade union movements, the menace of syndicalism will prove in the end to be, just as was the old Chartist movement, a stimulus to social reform and to industrial organisation.

The plain fact is that the rise in the cost of living is provoking a life-and-death struggle among a large proportion of our population which has been living on the poverty line. No spread of new revolutionary doctrines has caused the upheaval. Our people are as practical and direct in their aim as their fathers were. Responding to the fierce and sudden pressure of an antagonistic economic force, they have seized on the weapon of defence nearest to their hand, the general strike, and have

A MASS MEETING OF STRIKERS ON TOWER HILL IN THE SUMMER OF 1911

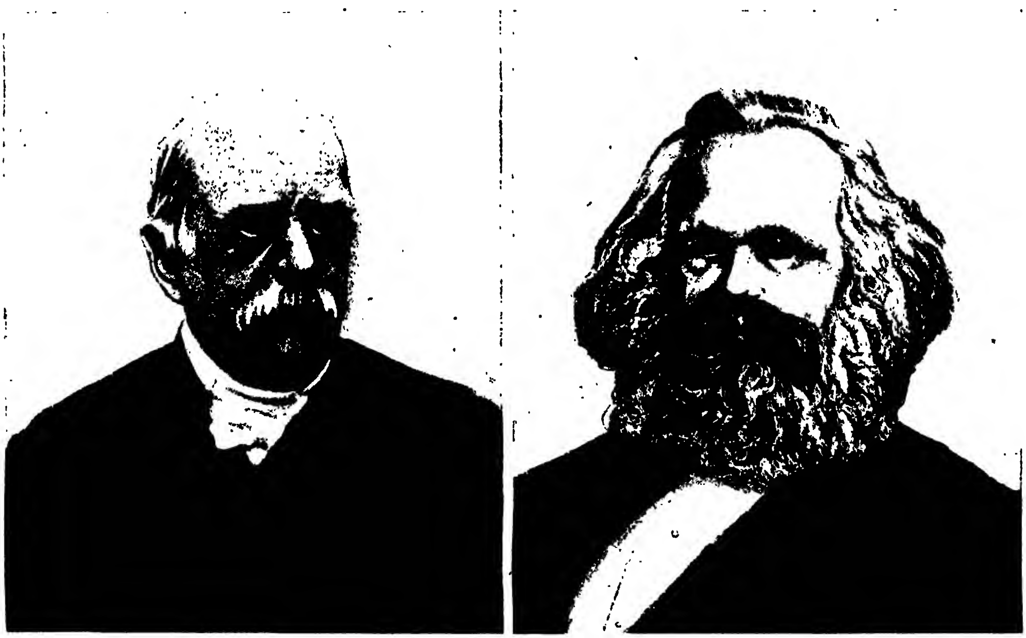
This fall in the actual food-value of every kind of labour is universal; and the fact that the working classes of our country have been the first violently to resent it is not altogether a bad sign. It at least shows that they have not lost the courage, the initiative, the fighting ability, by means of which their fathers won in considerable numbers a kind of aristocracy in the world of labour. It will be good for the nation if the general standard of life can be maintained against the new forces which are not merely threatening to degrade it, but actually are working strongly to lower the common level of subsistence. If the present movement of social unrest excites new hope and new energy and new ambitions in the lower-class labourers, who have begun to practise the use of it. Naturally, some of the well-organised trade unions have been the first to open the new era of industrial warfare. Being already ranged for battle, they have initiated the movement for a general rise in the standard of life. And though the colliers, for instance, by their recent strike, have knowingly inflicted widespread suffering on all other members of the working classes, yet there are some generous traits discernible in their warlike action. For most of the strikers stood to win nothing by a victory; they fought, by wrong means or right means, with the sole object of improving the position of the worst-paid members of their class.

Undoubtedly, it is deplorable from many points of view that our country should have

suddenly become the storm-centre of the industrial world. The strike and the lock-out are veiled forms of civil warfare, and, especially when they are used on a large and general scale, they provoke an amount of suffering and angry feeling that seems almost as dangerous to the structure of society as the armed dissensions of a people. And certainly a long and embittered strike in several important fields of national activity might develop into the revolution of famine which the French syndicalists dream of accomplishing. Yet, as our Royal Commission on Labour pointed out a few years ago, militant trade unionism represents an important advance in the solution of grave industrial conflicts. A notable passage in the report of the Commissioners is worth citing.

"Just as a modern war between two great European States, costly though it is, seems to represent a higher state of civilisation than the incessant local differences and border raids which occur in times or places where Governments are less strong and centralised, so on the whole an occasional great trade conflict, breaking in upon years of peace, seems to be preferable to continual local bickerings, stoppages of work, and petty conflicts. A large conflict of this kind is usually begun with cool deliberation, turns upon some real and substantial question, is carried on with less bitterness and violence, is properly settled by a regular and well-thought-out treaty of peace, and does not leave behind it much personal rancour or ill-feeling between individual employers and their workmen."

The Commissioners came to the conclusion that organisations of the great trade unions were more favourable to national stability than the unrest of a scattered host of feeble and disunited working folk. Trade unionism makes for long periods of armed peace, while in unorganised classes of labour there is more of the blind and destructive spirit of revolution; so that, on the whole, a general movement towards organisation among the lower-class labourers, now suffering from the increased cost of living, might eventually become a new source of national strength.



BISMARCK AND KARL MARX, WHO ADOPTED FRENCH POLITICAL IDEAS FOR GERMANY

All the sympathy and inventive genius and statesmanship of our race will be needed in working out the new settlement of our industrial society. We have to lead the world in modern social organisation, as our forefathers led it in political organisation, in mechanical invention, and in the command over natural resources. If we succeed in enlarging and strengthening the foundations of our State, we shall recover the inspiration and the energy necessary to develop and spread the religion of liberty, on which, ultimately, the welfare of the human race depends.

WHERE AMERICA LEADS

The Scientific Inquiries into Heredity Now Being Pursued Beyond the Atlantic in Music, Mathematics, and Tuberculosis

A SYSTEMATIC SEARCH FOR FACTS

We have already reached the conclusion, in this place, that any really trustworthy and useful knowledge of heredity in man, which alone can furnish the basis for Natural Eugenics, must be obtained by the exact method of analysis and study of each individual case, which Mendel introduced into biology some fifty years ago, but which has been so unfortunately neglected until our own time. We have seen, also, that the posthumous influence of the great founder of eugenics, Sir Francis Galton, has unfortunately led to the concentration of purely official eugenics in this country upon the method of mass statistics which has played us false invariably in this field, just because nothing but study of each individual case can furnish the truth of heredity in a being so complicated as man, and subjected to so complicated an environment, physical, social, spiritual.

Here our American contemporaries have had an immense initial advantage. They had not the historical prepossession in favour of the biometrical method, which Galton brought to eugenics in this country, and they had closer acquaintance with that wonderful American work in the heredity of animals, and especially of plants, to which a few conspicuous students in this country are just beginning to succeed in drawing effective attention. That work has shown that the exact facts of the particular individual must be studied first by themselves, and then in its ancestry and posterity in detail, together with the circumstances of environment of *each* of all these individuals. This is the way in which the American successes have been attained. It is the secret alike of Luther Burbank, whose results lead him rather to doubt the all-importance of Mendelism, and of Macdougal, the distinguished botanist whose experiments have greatly added to the scope of Mendelism. Wherever real results are obtained, whatever theory they may happen to favour, success has come by the one method of first-hand observation and experiment, not confusing nor averaging nor assuming, but noting the particular facts of each particular case. Nor need we be surprised at this; for when ever yet did science discover anything but just by this honest, hard, tiresome inquiry into the actual facts of Nature?

If this inquiry is hard and tiresome and slow when applied to the heredity of plants, it is immeasurably more so when applied to the heredity of man, whose generations are so long, who cannot be experimented with, whose families spread all over the earth so that they cannot be traced, who has pride and shame, and is liable to suppress and invent facts when the inquirer asks them, if, indeed, he does not simply kick the inquirer downstairs. Indeed, the difficulties of making a really useful inquiry into human heredity are almost, though not quite, insuperable; and that is the obvious reason why recourse has for so long been had to "short-cut" methods, which certainly avoid all these practical difficulties, but, while avoiding them, avoid also any chance of reaching the truth.

Now, as we have said, the Americans knew, for a certainty, that great practical results could be obtained, especially among plants, but also among animals, if the narrow and only safe path were chosen; and thus, when American interest in eugenics was created, chiefly by certain writings which had their origin here under the influence of Galton, and were widely disseminated in the United States, the conditions were right for the foundation of the American school of eugenics. Galton himself unfortunately died too soon to see the first fruits of that movement. Some

precise information respecting the movement must here be given, for the benefit of students on this side of the Atlantic.

A small committee on eugenics, established a few years ago, was the beginning in the United States. It included such distinguished men as Alexander Graham Bell and Luther Burbank, and leading biologists from Harvard, Chicago, Johns Hopkins, and Cornell Universities. Then in 1910 the American Breeders' Association took an important further step, for which every student of eugenics should now be grateful; indeed, the present writer finds it hard to say how much he values the new knowledge contained in the three "Bulletins" already issued, as a result of that step—knowledge which we shall discuss in the next chapter.

The new step was the supersession of the former committee by the formation of what is now known as the Eugenics Section of the American Breeders' Association. We observe that this body, dealing with human heredity and the possibility of human "good breeding," is definitely a section and development of an association which deals with heredity in the world of life below man, and with "good breeding" there of roses, racehorses, and so on.

The Eugenics Record Office Established in America on a Biological Basis

This development is strictly logical, as it should be, and it is particularly satisfactory, because it directly links the study of heredity and eugenics in man with the same studies in lower forms of life, thus avoiding one of the errors unfortunately made in this country—which was to place the study of eugenics in the hands of those who were not in touch with biology in general.

It need only be added, under this point, that the Chairman of this Eugenics Section is Dr. David Starr Jordan, the well-known botanist, whose work on "The Human Harvest," and the destruction of healthy manhood by war as a cause of the decline of Rome, has more than once been referred to in this work; and the Secretary of the section is Dr. C. B. Davenport, the leading Mendelian worker in the New World. To students of biology these names are of the highest augury, and we shall see in due course that our hopes have already, even within a year or two, been justified.

To any body of biologists it would be clear that the first business of Primary Eugenics is to obtain real knowledge of human heredity, comparable to that which we have lately begun to obtain regarding heredity in many animals and plants. Hence the first act of this new body was to form a Eugenics Record Office—a name which vividly recalls the founder of eugenics to the present writer, who remembers discussing with him the proposed name for his first effort of the kind in this country. Eugenics Record Office was, in fact, the name agreed upon, and the words might have been seen upon a humble enough door in Gower Street a few years ago, before Sir Francis Galton took the further step of establishing the Eugenics Laboratory.

The American Aim—that People May be Better Advised as to Fit and Unfit Marriages

The Americans have continued the name, but we shall see that there are very substantial differences in the methods which are employed. The Superintendent of the Eugenics Record Office is Mr. H. H. Laughlin; its address is Cold Spring Harbour, Long Island, New York: and anyone who has facts of human heredity, small or great, whether of mind or body, health or disease, provided that they really are attested and definitely recorded facts, is welcome to address correspondence there.

The following paragraph, taken from the publications of this new and important home of eugenics, is worthy of quotation:

"Established in connection with the Eugenics Section of the American Breeders' Association in 1910, this office aims to fill the need of a clearing-house for data concerning 'blood-lines' and family traits in America. It is accumulating and studying records of physical and mental characteristics of human families, to the end that the people may be better advised as to fit and unfit marriages. It issues blank schedules (sent on application) for the use of those who wish to preserve a record of their family histories."

Special Inquiries that Embrace Heredity in Mathematical Talent, Musical Talent, and Tuberculosis

We may conveniently begin our account of the work of this office by referring to the "blank schedules" mentioned in the paragraph quoted. Three schedules, now before the writer, deal with the three subjects to which the office is now devoting special attention; and we can only hope that the results will be comparable with those recorded in the bulletins already issued on insanity and feeble-mindedness, and later to be discussed here. The subjects now in question are mathematical talent, musical talent, and tuberculosis, and each of the schedules is worthy of careful study, for

they represent and display the *one* method by which our knowledge of these subjects can be extended—strict analysis of individual cases; and anyone who troubles to think and learn along these lines may himself or herself be in a position to make original and first-hand contributions to knowledge, which may be of very high and lasting value.

The general heading for the schedules that deal with mathematics and music is "Human pedigrees detailing the existence of specific biological traits," and we observe the word "specific." If modern genetics has taught us anything, it is that we must get down to definite *units* of the constitution of living things if we are to trace the facts of heredity. We must study "specific biological traits," not the resultant of any number of such traits, together with opportunity, opportunism, luck, good coaching, "back-stairs" influence, and no one knows what else, which play a part when we study the inheritance, so-called, of "success in examinations," "fellowship of learned societies" and the like. Further, we must note, as far as possible, the attendant circumstances, even when we do really believe that we are dealing with definite biological units, for environment or nurture matters today just as it did before we realised how much heredity matters also.

Points in the Schedule of Inquiry Respecting Hereditary Mathematical Skill

In the mathematical schedule spaces are found for the facts regarding any number of children, each parent, and each grandparent. We observe that three generations are included, for the American Eugenists are not repeating the lamentable waste of time and labour of the "biometricians" in this country, who have been content to study parents and offspring alone, and base large conclusions on such studies, though Mendel showed long ago that nothing has really been learnt regarding heredity until we can compare three generations, and trace the passage of characteristics from grandparents to grandchildren.

For each individual this schedule provides space under four headings (besides name and year of birth), namely: Natural aptness in mathematics; extent of mathematical training; degree and development of mathematical skill, and remarks and explanations. On the back of the schedule, the Office prints some important notes which show that the nature of the problem is really understood, and that, since "the question is being rightly put to Nature," as Bacon says, it may be rightly answered. Obviously, in the case under discussion, we want to draw the line between the influence of heredity and that of training. Mathematical skill is due to (1) Natural mathematical capacity, and (2) Training and experience in mathematics. Thus the schedule is designed so as to instruct us regarding the three distinct though closely related things—natural aptness, training thereof, and the consequent skill attained. And, further, it is pointed out that "present skill in mathematics is not the sole test of mathematical capacity. Two schoolchildren solve the same problem with equal facility; one may have studied very hard (mathematical capacity only '1' or '2'), the other prepared his work not at all (mathematical skill, probably '3' or '4')." Altogether, an admirably designed schedule, this, and we may hope for remarkable and valuable results from it in a year or two.

Evidence in Favour of Hereditary Talent for Music

In the schedule headed "Inheritance of Musical Talent," we see at once how far onwards the study of heredity for the purposes of eugenics has proceeded since Sir Francis Galton's great work on "Hereditary Genius" appeared in 1869. In that book (to which the reader can scarcely be referred, for it is out of print, as it certainly should not be) the author discusses various instances of inheritance of musical "genius" or ability; above all, of course, the notable case of the family which produced Johann Sebastian Bach, of whom all subsequent musicians are at any rate the spiritual descendants. We may certainly say that Galton's researches established a strong presumption in favour of some sort of inheritance of musical talent. But this inquiry of his, like all those which have subsequently been made by his method, suffered from lack of analysis.

The Extreme Complexity of the Factors Involved in Musical Genius

Everyone who has the slightest acquaintance with music knows how many factors are really involved in this question—of the ear, the memory, the taste, the intelligence, and so forth, each of these being heads under which many real "units" of musical talent and ability are included. Now, we believe that inheritance, among men or any other forms of life, is not of complexes, or happy conjunctions such as make genius, but of units, each of which is inherited, and distributed among the offspring according to its own laws, and the laws which couple

certain units and part others. These are the ideas which modern Mendelism has imposed upon us, and every day justifies them more certainly. Therefore we must apply new methods to the study of the problem, say of musical inheritance, if we are ever to reach conclusions which could possibly be of any use in eugenics. Let us now see how the schedule before us proposes to meet the new requirements.

It is, of course, prepared for details of three successive generations of the family to be recorded. That should now go without saying, though in this country voluminous reports are still being issued which deal with only two generations. After the spaces for the name and the year of birth of the individuals, there are provided no fewer than twenty columns, admirably devised, and certainly none too many, which must here be quoted, illustrating as they do the only way in which real and exact knowledge of heredity in the higher planes of man will ever be obtained.

The American Attempt to Make an Analysis of Musical Ability

The first two columns are grouped together under Appreciation of Music, and are headed respectively: (1) Ability to discriminate between good and common music and to thoroughly enjoy good music; and (2) extent of training in this particular. The next four columns are grouped under ability to sing, and are as follows: (3) Natural ability to "carry a tune," (4) perfection of time, (5) perfection of pitch, (6) perfection of quality. The next five columns are grouped under ability to play musical instruments, and are as follows: (7) Extent of voice training, (8) natural ability to "play by ear," (9) instrument played, (10) how well played, (11) extent of training in instrumental music. Then follow two columns that deal with reading music: (12) Facility in reading music; (13) extent of training in this particular; two on musical composition: (14) Skill in musical composition, (15) training in this particular; and two on theory of music: (16) Mastery of the higher forms of musical theory, (17) training in this particular. Column (18) is headed: What, if any, peculiarity of organs of voice or of hearing, or of hands, lips, teeth, tongue, or palate in any manner favouring or disfavouring facility in vocal or in instrumental music? (19) asks: Of how long standing is this peculiarity? And column (20) is headed: Summary—How would you grade this individual in general musical talent?

Among the explanatory notes of this long and remarkable schedule we find the following, well worthy of reading by any, amateurs or professionals, who may seek to extend our knowledge in this as yet almost unexplored field:

"Musical ability presents a very complicated case, due to the many types and the apparently great number of factors contributing to each type; accordingly, very great care must be taken to analyse the talent of each individual recorded in the pedigrees."

Points in the Inquiry that English Musicians May Study with Advantage

"For instance, column 1 is headed: 'The ability to discriminate between good and common music and to thoroughly enjoy good music.' It is noted that column 2 is a companion column to the first, both under the heading 'Appreciation of Music'; and the second is headed 'Extent of training in this particular.' Thus it is desired to draw the line as sharply as possible between the natural inherited musical sense and the training which would contribute to this result. Thus (*e.g.*), child No. 1 has spent several years in musical studies, but is still unable to discriminate between good and common music; in column 1, the figure 1 or perhaps 2 should be recorded; in column 2, the figure 3 or 4, or possibly 5, might be placed. And so on through the list."

Every musician who reads the foregoing will instantly realise the necessity of all this detail, as also the inherent difficulty of the problem which we are setting out to solve. It is not here asserted that the foregoing schedule is perfect, or that the task of discovering the laws, in the vast maze of records obtained, will be easy, even when thousands of these schedules have been conscientiously and carefully filled in, returned, and scrutinised. But this alone is the way in which the laws will ever be ascertained.

The Uselessness of Schedules of Inquiries Casually Drawn Up

Some years must elapse before even the first fruits of this inquiry can be expected. Meanwhile, the reader may note that already, from existing evidence, we have reason to suspect that the Mendelian law is illustrated in the inheritance of, at any rate, certain constituents of musical talent. And the writer cannot leave this schedule without expressing his gratitude to the American inquirers for the patience and skill and special knowledge which they

THE DREAMINGS OF YOUTH AND AGE

Alike in physique and in sentiment the first and third generations are often nearer together than the first and second, or the second and third generations.

Reproduced from the painting "The Dreamers," by permission of the artist, Mr. Tom Mostyn.

have devoted to its preparation, and his hope that they will be rewarded by patience and care in those who fill them in.

The method of preparing such schedules or "questionnaires" and sending them out to be filled in is anything but new. It has been employed in this country and on the Continent, as well as in America, for many years. The writer has done his best to fill in many such, on all manner of subjects, sent to him from the United States and from this country.

Why the American Inquiries Deserve and Receive Special Attention

The method is useful in many cases, above all in simple ones, as for instance when a questionnaire is sent round to a few thousand doctors, taken at random from the directory, asking whether they smoke, and, if so, what type of tobacco, and how much. But directly it is wished to ascertain anything so complicated as the laws of heredity, especially in such matters as musical talent, we run the risk of finding mares' nests galore, but real laws never.

This has already happened over and over again, and it would be easy to fill a chapter with the record of the futile and misleading inquiries which have been engaged in on these lines, only that they are better forgotten. The reason why these American schedules deserve and are receiving such special attention here is that, to anyone who has any acquaintance with the problems involved, these schedules are obviously of a new order, from which real knowledge may justly be expected—above all, because a serious and skilful attempt is being made to analyse the many and often almost inextricable "factors" or "units" which are concerned, and which we must get down to if we are to learn anything real at all about hereditary transmission.

The Urgent Need for a System of Inquiry into Tuberculosis

Let us turn now to the third schedule, which deals with the very different problem of tuberculosis. It must here be asserted, not for the first time nor the hundredth time, that *nothing is yet known* as to the inheritance of tuberculosis, except that the numerous positive assertions on the subject are worthless.

Schedules have been issued in this country, and figures have been subjected to actuarial treatment by the biometricians; numerous reports have been issued; the inheritance of tuberculosis has been positively asserted and is still positively asserted by Professor Karl Pearson, but, as the present writer has insisted, in controverting that assertion during the past seven years and more, no one has yet distinguished between heredity and infection in the treatment of the figures, and no figures or records exist which will enable any mathematician, however skilful, to distinguish between these two fundamentally different things. If the figures have no meaning, no manipulation of them will produce one, any more than the cleverest milling will produce flour from chaff.

Yet the subject is of the utmost and most urgent practical importance, in relation to eugenics and to public health, and to legislation regarding insurance, housing, care of school children, and so forth. The schedule now under discussion offers the first hope which any impartial student can recognise that we shall before long be able to pronounce definitely on some part, at any rate, of this complicated problem. The reader who has any appreciation of the colossal magnitude of the issues involved in this study of the causation of the most deadly of all diseases will be patient while we describe this schedule.

The Value of the American System, Covering Three Generations

It is to be hoped that the attention here drawn to it, for the first time in this country, may lead to the institution of similar inquiries here, where they are not one whit less necessary.

The schedule is prepared for three generations, of course; but that fact alone makes it unprecedented among the useless and dangerously misleading inquiries made in this country. An explanatory note deals with the important question of collaterals, also practically neglected by us hitherto: "In case any brother or sister of the father or mother of this recorded family has offspring, please enter a record of each such family on another form, assigning such brother or sister to the place of father or mother on the second form."

Failing the ideal but impracticable course of bodily reproducing this schedule for every reader of POPULAR SCIENCE, the best we can do here is to note the various headings under which information is sought, together with the explanatory notes and comments which may refer to them. After the name, sex, and year of birth of the individual, the "general health" is inquired into—a more or less useful preliminary, which may prove to be of no value or of much. The next

column is headed " Relation to Tuberculosis," and the filler of the schedule must state whether the indivinual in question has ever had tuberculosis actively, has had it and been cured, has it now, or had it at death. The next query is as to the diagnosis—whether the disease was diagnosed by the family physician, by a specialist, or by " common belief." This is exceedingly important; and neglect of accuracy and detail in this matter of diagnosis has frequently led inquirers to wrong conclusions, both as to the inheritance of tuberculosis and as to the utility of sanatoria in curing the disease. It is a pity that a column was not added in this schedule for a statement as to the discovery of tubercle bacilli in the case in question; no good sanatorium report can now be without definite statements under this head regarding every patient.

The next column asks as to the organ affected by tuberculosis if the individual under discussion had the disease at all; and the next asks the age at which the disease appeared—another point of high importance, for we are now beginning to suspect that this is really a disease of childhood, just like measles, whooping-cough, scarlet fever, and even small-pox in an unvaccinated community. The next column is headed " Infection," with the note: "If exposed to tuberculous persons, state whom —*e.g.*, sister, husband, fellow-workman."

Details of the American Inquiry into Tuberculosis, Showing its Thoroughness

This is a question of cardinal importance, which every year proves to be even more important; and it is a question wholly ignored by Professor Karl Pearson in those biometrical reports upon which he bases his condemnation of sanatoria and the other measures by which we hope to isolate the infection of this disease, as our ancestors isolated the infection of leprosy.

The next column is headed " Sanitation of Home," which is to be described as " exceptional (in cleanliness)," " intermediate," or " unsanitary." It should not need to be said, and yet it does need to be said, that the English inquiries into the supposed inheritance of tuberculosis, which have been used to argue against housing reform, and by the apologists of the slums, have ignored this factor of the cleanliness of the home (which means the whole question of tuberculous dust), though it is part and parcel of the whole problem of infection as against heredity.

The next three columns of this admirable schedule deal with bedroom ventilation at night—another point ignored by the English inquirers, simply because they began with the conviction that infection and environment do not matter in the disease. But the American Eugenics Record Office here inquire as to the bedroom ventilation of the individual, (*a*) in the winter, and (*b*) in the summer, first as to whether the window is wide open, slightly open, or closed, and second as to whether the " bedroom ventilates into open yard or country, street or alley, shaft, or another room only."

Ventilation and Alcohol in Relation to the Spread of Consumption

The importance of these inquiries is obvious; and it will be none the less obvious if analysis of all these answers, taken over many thousands of cases, should show that ventilation as such has been greatly overrated in importance by doctors, as there is much reason to suppose. Not that this comment is to be taken as decrying ventilation. It may only mean that scrupulous cleanliness and absence of dark dust, within the bedroom, are more important than the rate at which the air is changed.

The next query is as to the winter heating of the bedroom, whether " unheated, stove, cellar steam or hot-water heater, hot-air furnace, open fireplace." The next column is headed " Use of Alcohol," and is to be filled in either "habitual; sporadic; moderate; total abstainer." This column alone, which has no precedent in our inquiries here, should furnish most valuable information as to the relation between alcohol and tuberculosis, on which much knowledge, other than statistical, already exists.

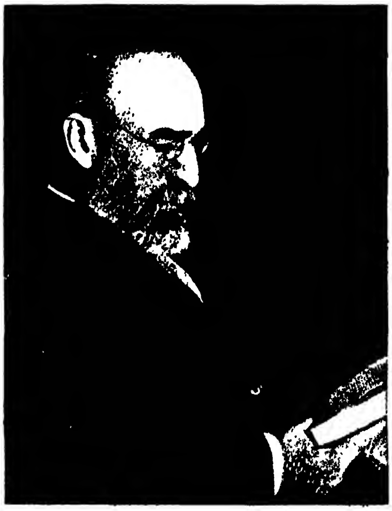
The Relation of Food and Temperament to Tuberculosis

The next column is headed " Food," and is to be filled in from the following: " habitual over-eater; moderate eater; insufficient eater; also fast or slow eater." The next is headed " Care of Health," for the inquirers wish to know, of each individual described, whether he or she is " careful, intermediate, or careless " as to health. Every doctor knows the interest of such an inquiry, for it is a familiar fact that the consumptive is often sanguine, and therefore careless, as to health. This is the " spes phthisica," or " phthisical hope," described by the physicians of classical times; and now at least we may expect, by means of the inquiry now under discussion, to ascertain the true relation of the temperament to the disease. Does the disease

produce it, or does the disease especially attack people of this temperament, owing to some inherent associated susceptibility to it, or does their carelessness simply expose them to it? Such are some of the questions which the thoughtful doctor has always asked, but never yet been able to answer with a satisfactory completeness.

The next column asks the principal occupation of the individual in question, or the occupation during the time the disease appeared. One has only to glance at the tables of our Registrar-General or at similar compilations to see what a close relation there is between certain occupations and the death-rate from tuberculosis. All this huge problem, which is and has been a matter for volumes, will receive real illumination, we may hope, from this new inquiry.

Further information is asked as to "any other diseases to which the individual is, or was, subject"—an inquiry of high importance to the doctor who knows how certain diseases are apt to be "complicated" by tuberculosis, but who does not know the facts of causation and the actual relation between the various "complications," as we call them in our present ignorance. The next column asks about the "bodily energy" of the individual, whether very active, medium, or slow; and the next as to the "characteristic mental state," whether prevailingly elated, prevailingly depressed, or alternately elated and depressed. Finally, if the individual is dead, the age at death and cause of death are to be stated. Below these numerous columns, not one of which is superfluous, space is left for remarks on other points, and for description of any other family traits which are thought worthy of note. The Eugenics Record Office add that "every accurate family record is of great value; and in case additional families with histories of tuberculosis can be recorded, the Record Office will, on request, send on additional blanks for such purpose." In the present writer's judgment, the words "with histories of tuberculosis" are quite unnecessary. We shall learn no less about tuberculosis from families that have *no history of it*; and this is just the part of the whole inquiry which has been most neglected hitherto. We want to be able to compare and contrast the records, habits, occupations, of families in which the disease is rife with those of families which it has left unscathed; and though there are few enough of these latter, the records of them will be all the more significant. Lastly, the two initial paragraphs of the notes upon this schedule may be quoted: "The information called for on the other side of this blank is wanted solely for scientific study, and will be held in strictest confidence. Through the study of this and similar records, it is hoped to be able to determine the laws governing the inheritance of resistance and non-resistance to tuberculosis. Each blank should be filled out with care and frankness—inaccurate or incorrect statements are worse than none."



DR. DAVID STARR JORDAN

So much for these three schedules, and our expectation of substantial additions to knowledge on the three subjects to which they refer. If a prophecy may be hazarded, it is that the importance of hereditary transmission will be proved to be transcendent in the production of musical and mathematical talent, though many additional questions would have been desirable, notably regarding the existence of "tone-deafness" at the one extreme, and "sense of absolute pitch" at the other. But as regards tuberculosis, which is due to a microbe, and thus has an essential factor of causation that has no parallel in the case of musical or mathematical ability, we may expect that the importance of environment, habits, and infection will be found to be dominant. Indeed, as regards tuberculosis, it may be said that the American inquiry is chiefly needed in order to confirm the existing evidence, and in order to allocate their due share of responsibility to the various factors of nurture—such as ventilation, cleanliness, alcohol, and diet.

And now, having thus cleared the way, we may proceed to study the three bulletins already issued by the American Eugenics Record Office, and to observe the valuable and surprising new contributions to knowledge which they contain.

THE SURFACE OF THE MOON

Its Craters, Mountains, Level Plains, Valleys, and Ray-like Brightnesses, with Conjectures as to Their Causes

THE UNIVERSE AS SEEN FROM THE MOON

THE craters of the moon cannot be seen by the unaided eye. They were discovered in 1609 by the inventor of the telescope, Galileo, who described them accurately as ring-like mountains around depressions, and even attempted to measure their altitude, arriving at an estimate very much the same as that which is held today. The method still adopted for determining the height of the crater walls is by the measurement of the length of the shadows they cast, and it is found that some of them reach the great height of 20,000 to 25,000 feet.

Many theories have been brought forward with regard to the origin of these pits scattered so freely over the greater part of the moon's surface. For instance, they have been explained as the remains of broken bubbles formed in highly tenacious molten lava. In support of this theory, it may be said that huge bubbles are sometimes formed in highly viscous lavas of the earth's surface, and that these bubbles, which may be many feet in diameter, leave ring-shaped elevations when they burst. Broken lava-bubbles produce an appearance strikingly resembling the lunar craters, except that they do not produce the central cone which is so characteristic of these structures. Moreover, gravity on the surface of the moon is only one-sixth of what it is on the surface of the earth, so that very much larger bubbles could be produced there than on earth. Yet, even though we allow for the highest possible tenacity of the materials, we can hardly believe in the existence of lava-bubbles ten, fifty, or a hundred miles in diameter.

Another view holds that each crater is due to a very limited but very powerful explosion within the materials of the moon's surface, acting equally in every direction, and so throwing up a circular rampart of lava that cooled into the form we now see. This view fails, not only because of the great regularity of the craters, but also because of the steepness of their walls. These walls have an average slope of forty degrees on the outside, and are even steeper on the inside; and vast masses of lava thrown up in the molten condition into prodigiously high walls of such steepness would certainly not cool and solidify in that position.

A third conjecture is that the craters are the result of local whirlpool movements in the molten materials of the moon's surface, during the process of solidification. A fourth holds that the site of each pit was formerly a lake fed by hot springs, and that the moisture, evaporating from the surface of the lake, was precipitated as snow all round it, thus building up circular walls of ice which remain to this day as the crater walls. Neither of these theories is really tenable. As against the latter, it may be pointed out that, though ice flows slowly, it does flow, as we know from the glaciers of the earth; and that these supposed walls of ice would therefore have been flattened out ages ago.

A fifth theory, which has had not a few supporters, regards each crater as the spot where some separate mass of matter, travelling through celestial space, has fallen upon the moon and entered her surface. It is supposed that the moon was formed by the collision and coalescence of meteorites circling in swarms round the earth, and that her surface still preserves the marks of the final stages of this process. This meteoric theory has been illustrated by certain very striking observations; thus, clay balls shot into a clay surface give astonishing resemblances to the craters, and raindrops falling on mud produce not only ring-walls but sometimes even the central cone of the pit floor. Yet, ingenious

though it is, this view of crater formation is disqualified by several objections we may briefly enumerate.

First, a mass entering the moon's surface at so great a velocity would generate so much heat as to melt down any crater walls it might throw up, and to melt down also a considerable area of the surrounding regions. In fact, it would produce an extensive flow of very hot lava, which would congeal in a smooth and level surface, similar to the surface of the so-called seas, or *maria*, of the moon.

Objections to the View that the Moon's Craters were Formed by Falling Meteorites

Secondly, not all the masses thus striking the moon would fall vertically upon her; many would enter her surface more or less obliquely—yet all the pits are exactly vertical. Thirdly, if the moon were formed by the coalescence of separate masses, as may very well have been the case, the smaller bodies must have been the first to join, and the larger, having greater independent momentum, must have been the last to enter. But the largest pits were the first, and the smallest pits were the last, to be formed, as is shown by a great number of instances where the crater walls of two pits of different size intersect one another. And, finally, this meteoric theory, like others, fails to account for the steepness of the lava walls. Notwithstanding the comparatively slight effect of gravity on the moon's surface, there is no ground for believing that lava, thrown up in the molten condition into walls of such mountainous elevation, could cool and solidify so suddenly as to retain that form

We have not collected all the theories with regard to the formation of the craters. But these conjectures, and others like them, may well be set aside, not only because of the specific objections that may be brought against them, but chiefly because there is no reason to try to believe in them until we have exhausted the possibilities of a simpler and more probable explanation.

The Theory that the Craters were Formec by Volcanoes of a Quiet Type

These structures look like craters; they look like the work of volcanic processes; and it is reasonable to suppose that their origin is truly volcanic until we have some definite proof to the contrary.

We have on earth two very different types of volcanoes—namely, the eruptive and the quiet volcanoes. The former kind, including volcanoes such as Vesuvius, Krakatoa, and Mont Pelée, is by far the more frequent of the two, and its main features are known to everyone. These volcanoes from time to time discharge steam and scorching gases, bury surrounding districts in ashes, or pour forth devastating streams of lava, and have thus caused some of the most dreadful disasters in history. It is certain that the volcanoes of the moon have not been of this type. But their craters resemble in the most striking way the craters formed on earth by volcanoes of the quiet type. When we speak of quiet volcanoes we do not refer to eruptive volcanoes in a quiescent or extinct condition, but to an entirely distinct kind of volcano. These quiet volcanoes are much less generally known than volcanoes of the eruptive type, because they are less numerous, more remote, and their performances are less sensational.

The largest volcanoes of this quiet kind are in the island of Hawaii, in the Pacific. This island, eighty miles in diameter, and rising to a height of 14,000 feet above the sea, or 30,000 feet above the sea-bottom, has been built up by the activity of four quiet volcanoes.

A Volcano on the Earth that is Probably Like the Moon's Volcanoes

Mauna Loa, one of these craters, is three miles in diameter, and has a depth of 1000 feet; and when inactive it has a hard floor of solid lava upon which it is possible to walk. When eruptions occur, the floor rises, its cracks open into fissures through which lava spouts and streams, and the crater becomes a lake of molten lava whose surface rises until it quietly overflows the rim of the crater, or escapes through rifts in the mountain side. The effect of an eruption is generally to enlarge the crater; to build up the outside of its walls by the streams of lava which pour down them, and, on occasions when the molten lava overtops the rim, to build the walls still higher. After eruption the level of the lava sinks in the crater, and a new floor is formed by the cooling of its surface. These eruptions are slow, gradual, and silent. Kilauea, another crater in the same island, and of nearly the same diameter, behaves in an identical way, except that in this case the central cone, which is so characteristic of the craters of the moon, has been observed. A cone, four hundred feet in height, containing a lake of molten lava, was built up during a few years from the centre of the crater floor. Indeed, the craters of these quiet volcanoes of Hawaii resemble those of the moon in every respect in which they can be compared. It is true

that the lunar craters are in many cases much larger, but it must be remembered, on the one hand, that the force of gravity is much less on the moon than on earth; and, on the other hand, that volcanic activity has taken place on a very much greater scale there than here.

There is reason to believe that at an early stage in her history the moon was a globe of viscous consistency, much closer to the earth than at present, rotating much more rapidly than she now does on her own axis, and revolving also round the earth.

The Manner in which Lunar Craters most Probably were Formed

The surface of the moon, under these conditions, must have been subject to tides of immense force; and as the surface began to cool sufficiently to solidify into a thin crust, this crust, contracting round its contents, must have been easily cracked at any points of weakness, by the force of these enormous tides. The liquid interior, issuing forth at these fissures, would then form craters of the type we have described above. The vast and ancient craters of a hundred miles or more diameter would be formed in the earlier stages of the solidification of the moon's surface, followed in later stages by craters of ever diminishing size.

In accordance with this theory, we find that the linear arrangement of the more ancient craters, in so far as they have any, is mainly in the north and south direction, or, plainly, the direction in which these powerful tides would rend the crust; and we find also that the smallest and most recent craters are developed in lines and series, sometimes hundreds of miles long, lying along obvious cracks in the surface, which often radiate from the sites of the more ancient pits.

Is there Volcanic Activity on the Moon at the Present Time?

The question has often been raised whether there are any signs of volcanic activity going on at present in the moon. It is not possible to deny absolutely that there may be some remains of activity, but the weight of the evidence goes to show that the moon is in this respect extinct. Her surface has been very closely studied by several generations of students, and any signs of change that can be brought forward are very slight indeed. There are areas which change from time to time in colour, in a way that is supposed to indicate the discharge of fumes from certain small craters. There are also craters which appear to change in shape during the advance of the lunar day. For both of these cases sufficient explanation may probably be found in changing appearances caused by variations in the angle and direction of the sun's rays. Even the most remarkable instance of an alteration in the moon's surface may perhaps be explained in that way. A crater named Linné was formerly six miles in diameter, and had clearly marked steep walls, but was discovered in 1866 to have undergone great changes, so that instead of the old crater there was a white spot more than ten miles in diameter, within which there was now a very small crater. Of course, the rocks of crater walls, subjected alternately to the fierce heat of the sun and to the great cold of the lunar night, cannot but be affected by the consequent expansion and contraction of their materials, so as to be ultimately broken down. Linné may have been in a very unstable condition, and may then have been shattered by the blow of a meteor, filling the crater with the exception of a narrow space in the centre. Possibly, on the other hand, the earlier observers may have measured and drawn it incorrectly. Or, as is most likely, it is a structure whose appearance differs more than usual under different conditions of illumination. Certainly, observations of it in recent years have given varying results.

A Classification of the Lunar Structures that are Apparently Volcanic

All these crater-like volcanic structures on the surface of the moon have been classified into six groups, chiefly according to their size, as follows: 1. "Walled plains," the vast craters surrounded by great walls, and often studded with pits of smaller size and later date. 2. "Mountain rings," the remains of similar huge craters, now seen in various degrees of demolition in the seas, or *maria*, which we have yet to study. These "mountain rings" are found only in the seas, and their differences from the first group depend only on that situation. 3. "Ring plains," the strongly walled pits, of great diameter, with steep inner sides to their walls. These differ from the first group chiefly in respect of the greater distinctness and regularity of their structure. 4. "Craters," the walled pits less than about fifteen miles in diameter. 5. "Crater cones," small pits, usually less than a mile in diameter, resembling conical depressions in the lunar surface. 6. "Craterlets," the smallest pits of all. It is necessary to mention this classification, as these terms are often used in descriptions

of the moon's surface. But the several groups run into one another, and the classification is really arbitrary.

The irregular but roughly circular level plains which have received the name of seas, or, in Latin, *maria*, cover about a third of the visible surface of the moon, chiefly in the northern hemisphere. Each of them is vastly more extensive than the greatest of the craters. They are distinguished from the rest of the surface not only by their smoothness, but also, more conspicuously, by their much darker colour. They are not by any means free from craters, but craters are much more sparsely scattered over the surface of the seas than over other regions; and those craters which occur on the seas are comparatively small, having diameters not exceeding ten or twelve miles, and are therefore recent. The ruins of huge craters are, however, to be seen here and there within the seas.

The margins of the seas are not enclosed, like the volcanic pits, with mountainous rings; they resemble very closely the shores of real seas of water, in the way by which they appear to have flowed in among the surrounding elevations, thus forming bays, or to have been limited in other places by gently rising ground.

Two Conjectural Accounts of the Formation of the Lunar Seas

Where the sea's margin has come against the outside of a crater, it has sometimes melted away the crater's wall, leaving only a portion of the circle standing, and the sea has flowed within the crater; and in the same way, as we have already seen, the partially melted remains of great craters, antecedent to the formation of the seas, may be observed in the midst of their area.

There are two chief theories with regard to the formation of the seas. One of them holds that each sea was formed by the impact of a huge mass, falling from space, upon the moon's surface. It can hardly be questioned that a collision of that kind might very well produce all the effects which we see. It would generate enormous heat, sufficient to melt the foreign mass itself, together with a large area of the surrounding country, thus forming a vast lake of very fluid lava which would melt down everything against which it flowed, until finally it cooled as a level plain of irregularly circular outline. On the surface of this plain, at a later date, the formation of craters would again begin, but the craters would, of course, be fewer, as well as smaller, than elsewhere. The other theory has the advantage that it does not demand the fall of vast meteors out of space, but explains the formation of the seas in what is perhaps a simpler way. After a thin but comparatively rigid crust had been formed upon the surface of the moon, the contraction by cooling of the interior would require a corresponding contraction of the crust. But this crust was pitted with craters and honeycombed with cavities. It is suggested that in certain regions, where craters were exceptionally large and numerous, considerable areas of the crust may have fallen in upon the molten material below, and, being denser than the latter, because solid, may have sunk, or partially sunk, and so have become melted. In this way a fresh surface would evidently be formed. This sinking and melting of the crust has been seen again and again in the craters of the island of Hawaii.

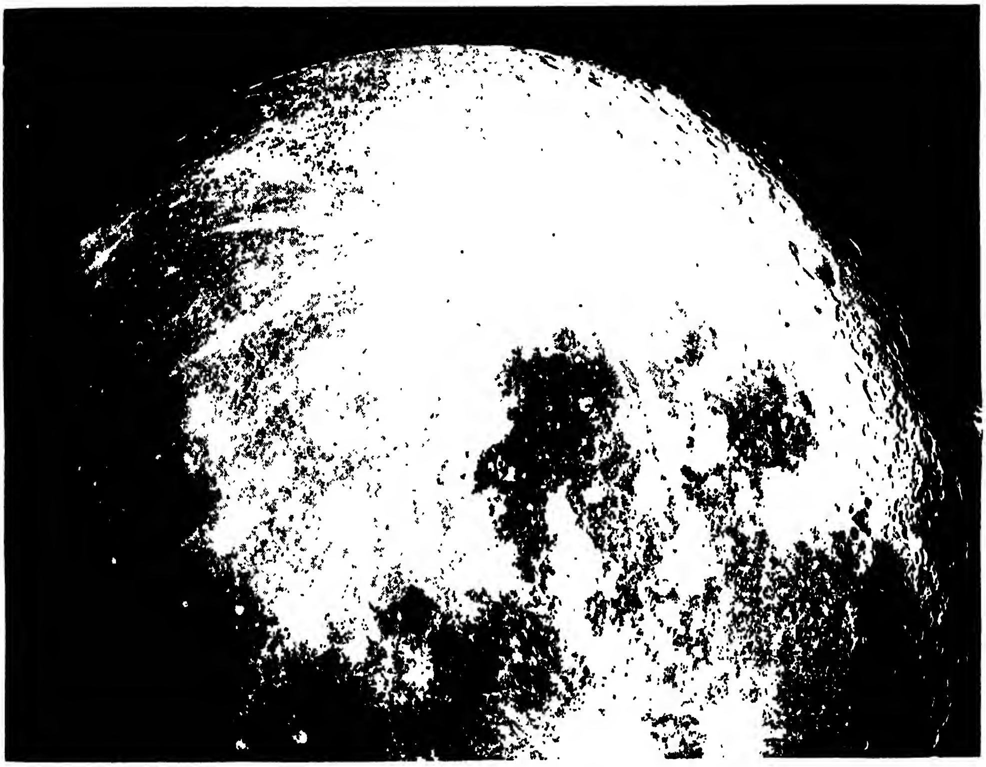
Suggested Reasons Why the Moon's "Seas" are Dark in Colour

The difference of colour between the seas and the other portions of the moon is explained, according to this theory, on the supposition that, prior to the formation of any crust upon the moon, the materials of least specific gravity were presumably separated out, and floated upon the surface of the viscous globe; so that the crust, when formed, consisted of special materials, differing from those below. The materials of the crust were evidently of lighter colour than those which underlay them. When, therefore, certain portions of the crust fell in, and a new surface was formed by the subjacent lava, this new surface, besides being smoother, was also of darker colour than the surrounding regions. It is consistent with this theory, also, that the surfaces of the seas, though not all at the same level, are all depressed below the level of the general surface of the moon.

The Jagged Mountain Regions of the Moon and Their Probable Formation

The general surface of the moon is extremely rugged. In addition to the mountainous walls of the craters, the moon has many clearly marked mountain regions. These can hardly be called mountain ranges, because the peaks are massed together over wide areas rather than grouped in long chains. The mountain systems of the moon, which have received names from the terrestrial ranges, such as Alps, Apennines, etc., contain fragments of huge ancient crater walls, showing that the development of the mountains has been later than that of the largest volcanic pits. In regions where the crumpling of the crust has thrown up these

confused areas of precipitous heights, the old ring walls have been broken up and their ruins have been elevated together with the surrounding surface. More recent and therefore smaller craters have in many cases been formed in mountain regions after the mountains had been built. Besides these high mountain systems of the moon, there are also ridges of slight elevation and narrow width, but of great length, on the surface of the seas. All the mountains of the moon are extremely steep, jagged, and tumbled in appearance, and consist of masses of lava broken and thrust upward when solid.



THE SOUTH POLAR REGION OF THE MOON, SHOWING THE BRIGHT DIVERGENT RAYS
From a photograph by M. P. Puiseux, taken at the Paris Observatory.

The rills or valleys of the moon are clefts or cracks in its surface, having very steep sides and often are very deep. They are called valleys when they are wider, rills when they are narrower. Some astronomers have thought that the rills are series of minute craters so near to one another as to give the appearance of continuous lines, which often branch and may be several hundred miles in length, but the most capable observers give no support to this view. They regard them as simply cracks in the crust, formed by great pressure from the interior, after that pressure had ceased to be relieved sufficiently by volcanic action. The rills are therefore of comparatively recent date, and are probably the latest of all the structures formed upon the moon. At least a thousand of these cracks have been recognised and mapped, and there must be many thousand more.

There are, however, rills of a special kind which, according to some authorities, appear to have been river beds. These differ in four respects from the great majority of rills—namely, they are always wider at one end than at the other ; the wide end runs into a pit or depression in the surface ; the course of these rills curves and meanders in exactly the same way as terrestrial rivers do : and, finally, one end of the river bed is at a greater elevation than the other. In the case of these lunar river beds, if such they be, the wide end is higher than the narrow end ; and it is supposed that each river originated from geyser springs in a lake, now represented by a pear-shaped depression, and wandered in its bed across the desert country until its water had been exhausted by evaporation. The largest of these river

beds is 120 miles long, and three miles wide at its point of origin.

By far the most puzzling feature of the surface of the moon consists of certain areas which become extraordinarily bright for a part of the lunar day, but are indistinguishable in respect of brightness from the surrounding areas during the earlier and later portions of the day. That is to say, when the sun's rays fall very obliquely on them, their special quality, whatever it may be, is invisible; but when the sunlight falls on them more vertically, they become not only visible but extremely conspicuous from their brilliancy. Moreover, they can be made out clearly on the "old moon in the new moon's arms," by the vertical rays of earthshine.

The Areas of Variable Brightness with Radiating Bands of Light

These areas of variable brightness, which shine out under a comparatively vertical light, but are obscured under an oblique light, are large, irregular patches including the summits and higher slopes of the crater walls. From these patches of excessive brightness there extend in some cases, about thirty in number, very remarkable systems of rays having the same quality of great brilliancy under a high sun. Thus, from the shining patch around a great crater there may extend in every direction shining filaments or bands of the same character, each band being very narrow, but many of them attaining an extraordinary length, so that in an extreme case a length of 1700 miles has been measured. Some of these systems of bright rays are the most beautiful as well as the most conspicuous objects on the surface of the moon.

It is certain that the bright rays or bands of this kind do not correspond with rills or clefts such as we have already considered. They are remarkably straight, traversing every irregularity of the surface, whereas those cracks in the moon's crust pursue very irregular and often branching courses.

Appearances Visible in Earthshine that Have No Earthly Analogy

A bright ray has been traced to the edge of a crater, across its floor, up the opposite wall, and then again down the outer slopes of the wall and away across the country. Sometimes the rays of one system cross those of another, without any apparent mutual interference.

The nature of these patches of brightness and of the systems of bright rays which proceed from many of them has been much discussed, with little satisfactory result. There is no doubt that they present a problem for which we have no terrestrial analogy. The fact that they are visible by earthshine proves that their first appearance after the sun has risen upon them for some time is not due to the fact that they are produced by the sun's light or heat. Evidently they are there all the time; only the conditions of their visibility, and not they themselves, are subject to this periodic variation. They are due to some deposit over certain areas, of materials which shine very brightly when the sun is high, but are invisible when the sun is low.

It is possible that they consist of materials of crystalline texture, the surfaces of the crystals being mainly horizontal. These crystalline materials may have been thrown up in volcanic action, so as to cover the surface of the crater walls; and they may have escaped also from the interior, along immensely long radial cracks in the moon's surface, probably in the form of vapour which has condensed and become deposited along the neighbourhood of each of these cracks, so as to constitute the systems of bright rays. That is one theory, in which however, it is hardly possible to believe. These immensely long, straight cracks are really out of the question.

Do the Bright Patches and Bright Rays Round the Craters Consist of Snow?

This theory may be considerably amended and may become fairly tenable if we suppose that the vapours, which were to be deposited as brightly shining crystals, proceeded as fumes from the interior of the craters, and, besides becoming condensed in a crystalline coating over the crater walls and the immediate neighbourhood, were guided in radial currents by directing forces of an electrical or magnetic nature, which we can only guess at, but cannot more clearly define. The disposition of the bright rays is of such a remarkable nature as to be unaccountable except by some influence of that kind. No explanation is here offered; the problem is unsolved, but the solution, when it is found, will most likely lie in the direction indicated.

Assuming some directing influence of a magnetic kind, which governs the radial direction of the bright bands and filaments in these systems, the most satisfactory suggestion which has yet been made appears to be that the irregular bright patches around the high craters, and the bright rays proceeding from those patches, consist of snow or hoar frost. The moon's surface is very irregular, and its sky is black,

so that frost or snow lying in depressions over great areas would be unlighted, and therefore invisible under oblique illumination, but would shine out with extraordinary brilliancy as soon as the source of light became more nearly vertical so as to reach it. The subject is a complicated and difficult one, but the probability is that the bright rays and bright patches consist of snow.

The question has often been raised whether there may or may not be inhabitants upon the moon. It is a perfectly idle question, because, on the one hand, there is no conceivable reason why there should be any such inhabitants; and, on the other hand, there can be no conceivable proof that there are none. Certainly there are not any whose physical conditions resemble our own; but we have no ground for asserting that the inner life of perception, feeling, reason, and will may not be bound up with bodies very different from ours, and having very different physical needs. Ingenuity expended on a subject of that kind is altogether thrown away. It is not so idle, however, to consider, as many astronomers have done, what may be the aspect of things as seen from the moon, because this imaginative outlook from the lunar point of view helps us to realise more concretely the differences between the earth and her satellite.

The Desert Scenery of the Moon which No Artist can Pourtray

With this purpose, landscapes have often been drawn of portions of the moon's surface, as seen, for instance, from the summit of a crater wall; and the artist has attempted not only to introduce the most characteristic features which can be made out with the telescope, but also to give effect to the absence of water and of an atmosphere. The clouds, hills, valleys, plains, and vegetation of earth, including practically all that can be seen in any landscape, owe all their pictorial character to the effects of water—water rising in evaporation, condensed in the air, falling in rain, running in streams, shaping the hills, excavating the valleys, laying out the plains, and clothing the earth with green. In those regions of earth where water is deficient, we have desert scenery, but the lunar landscape is more desolate by far than any desert, for desert scenery is the work of wind and wind-blown sand, and the moon has no winds—only an eternal soundless calm. Again, in an earthly landscape, "atmosphere" is nearly everything; the whole range of tones from the foreground to the remotest distance depends on atmosphere alone. But the landscape of the moon is neither softened nor varied by atmosphere; every detail, near and far, must strike the eye with the same appalling distinctness. Every shadow must be dead black, with hard edges; and the whole effect of the scene must practically be one of black and white.

Yet more dreadful even than this lonely desolation must be the aspect of the heavens. We cannot say the "sky," because of the sky, as we know it, there can be none. The moon has none of this homely, bright, warm shelter of blue and mist and cloud, no sunset hues, no purple gloom of night; she is exposed throughout her day, as in her night, to the outer darkness of infinity, a blackness swarming with myriads of celestial lights.

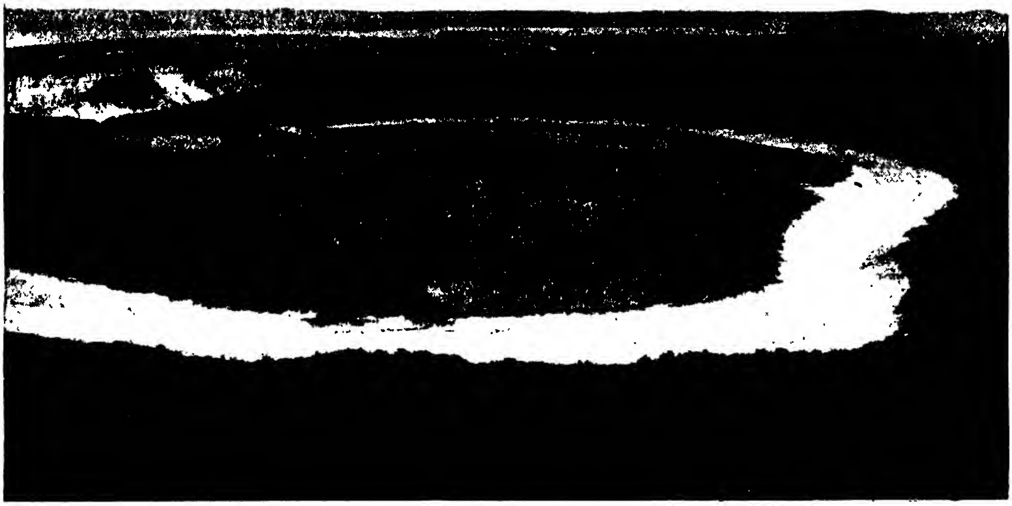
The Wonders of the Flaming Sun as They Would be Seen from the Moon

An innumerable multitude of stars, too faint to be seen on earth, are visible from the airless moon. Here, as never on earth, the sun is seen unveiled in all his glory. Around his brilliant white mantle of incandescent clouds, which alone we see from earth, the inhabitants of the moon, if such there be, see the flaming chromosphere scintillating with every colour, and shooting up from this the far-reaching prominences, also of blending and changing hues, some of them shaping and drifting like clouds, others towering like prodigious flames and jets of molten metal. Around the chromosphere and prominences, again, they see the threads and streamers of the corona; and far beyond the corona they see the vast zodiacal light, streaming from the sun in each direction for a distance of more than sixty times his diameter.

Where the Earth Appears a Huge Luminary Mellowed by the Shining of the Stars

From that surface of the moon which we see the earth is always visible, clearly marked with clouds, continents, oceans, and Polar snows. The earth forms a huge luminary, passing through phases, just like those of our moon, from new to full, and then again to new; but the outline of her globe is always marked by a ring of brilliant light—namely the light of the stars behind her, diffused and shining in her atmosphere. Yet, to the dweller on the moon, neither the incomparable splendour of the sun, nor that great flood of earthshine, can veil the eternal glitter of the constellations, in heavens black with a darkness of which our blackest night can give no true idea.

BETWEEN TINTERN AND CHEPSTOW



Not only is the scenery of the Monmouthshire Wye among the most beautiful in England, but the river is typical in a high degree. Through mountain gorges and pastoral peace it reaches a tidal exit to the Severn estuary. The lower picture shows how the tidal flow is wearing a way through one of the river's bends, and in the upper picture the meandering course is seen near the renowned Windcliffe.

The photographs on these pages are by Donald McLeish, the Photochrom Company, and Underwood & Underwood

THE RETURN OF THE WATERS

The Sources, Tracks, Windings, Vagaries, Volume, Colour, and Taste of Rivers

DISTRIBUTION OF THE CHIEF RIVERS

RIVERS may be defined as streams of fresh water of considerable size which run downhill, and ultimately flow either into the sea or into an inland lake. The water is, directly or indirectly, rain or melted snow. Again, it is vapour from the sea that makes the rain and snow. And so we have a constant circulation of water—sea, rain, river, sea, rain, river—"into the place from whence the rivers come, thither they return again."

Looking at the matter in another aspect, we may say that a river is a product of evaporation, condensation, and gravitation. The water vapour evaporated from the sea is condensed into rain, and the rain, falling upon the irregular land, is gathered together into certain channels by gravitation, and led downwards to the sea again. Here we see one of the many missions of the mountains. The cold, rough hands of the mountains it is that clutch the clouds and condense the rain; the mountains it is that give gravitation its opportunity and its direction. Wherever there are mountain ranges we have cold condensing surfaces; and where the peaks are snowy or icy their efficacy as condensers is naturally increased. Well known are the cloudcaps that so many mountains wear, and the cloud-banners that stream away from snowy or icy peaks when a wet wind blows.

With his customary eloquence, Ruskin describes the relationship of mountain and river: "Every fountain and river, from the inch-deep streamlet that crosses the village lane in trembling clearness, to the massy and silent march of the everlasting multitude of waters in Amazon or Ganges, owe their play and purity and power to the ordained elevation of the earth. Gentle or steep, extended or abrupt, some determined slope of the earth's surface is of course necessary before any wave can so much as overtake one sedge in its pilgrimage; and how seldom do we enough consider, as we walk beside the margins of our pleasant brooks, how beautiful and wonderful is the ordinance—of which every blade of grass that waves in their clear waters is a perpetual sign—that the dew and rain fallen on the face of the earth shall find no resting-place; shall find, on the contrary, fixed channels traced for them from the ravines of the central crests down which they roar in sudden ranks of foam to the dark hollows beneath the banks of lowland pasture, round which they must circle slowly among the stems and beneath the leaves of the lilies; paths prepared for them by which, at some appointed rate of journey, they must evermore descend, sometimes slow, and sometimes swift, but never pausing; the daily portion of the earth they have to glide over marked for them at each successive sunrise; the place which has known them knowing them no more; and the gateways of guarding mountains opened for them in cleft and chasm, none letting them in their pilgrimage, and from afar off the great heart of the sea calling them to itself: 'Deep calleth unto deep'!"

But the mountains do more than gather and condense rain to make rivers; they also store it. When man wishes to store water he builds huge tanks and reservoirs, but when Nature wishes to store water she collects it in spongy mountain marshes and boglands, or she freezes it into snow and ice. Snow and ice especially are Nature's contrivance to build up a reserve of water against summer drought. All winter, when the rainfall is heavy, she piles up enough snow and ice to make cataracts in the spring, and to irrigate the lowlands in the summer. The same sun she used to lift the water she uses to thaw it. In the summer many rivers would be dried up

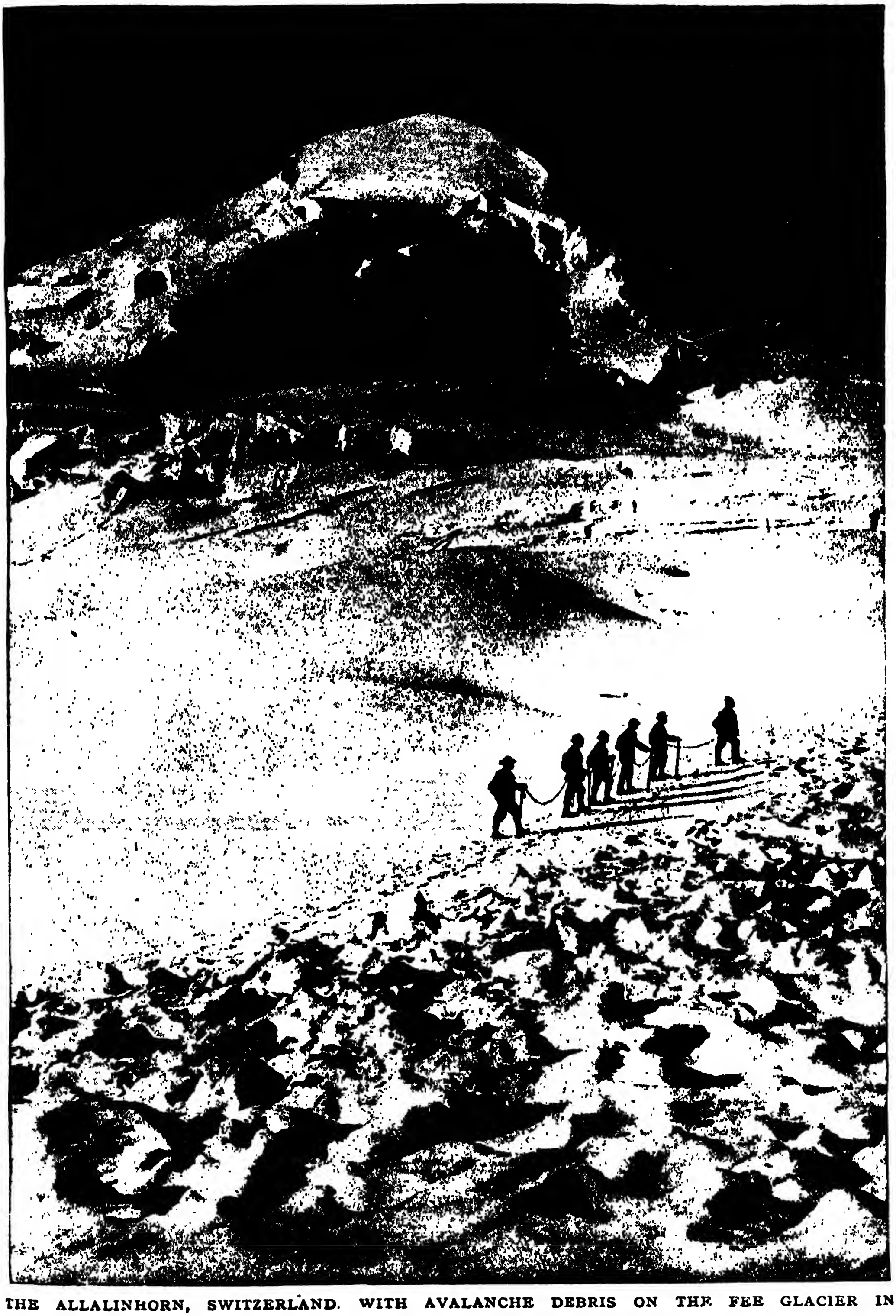
just when most needed were it not for this cold storage.

In every country and continent it will be found that there are elevated lines and mountain ranges which produce slopes in opposite directions, and thus direct the course of running water either one way or another, more or less after the manner of the roof of a house. These directive elevations are known as "watersheds," or water-partings. A watershed, or water-parting, is indeed the intersecting line of two divergent slopes causing diverging rivers. When we study the watershed lines of England we find that a line runs north and south from Scotland through the Midland Counties to Salisbury Plain, where it bifurcates into two branches—one running eastwards towards Dover, and one westwards towards the Land's End.

A watershed often has momentous consequences. The watershed, for instance, known as the "Great Divide," in Central North America, decides whether rain shall flow into the Pacific or into the Atlantic. Two streams of water, rising a few feet or inches apart on a plateau in the interior of Brazil, may reach the Atlantic thousands of miles apart. A few inches eastwards or westwards, northwards or southwards,

SUNSHINE ABOVE AND RAIN BELOW—A CLOUD THAT CONDENSES ON MEETING A MOUNTAIN

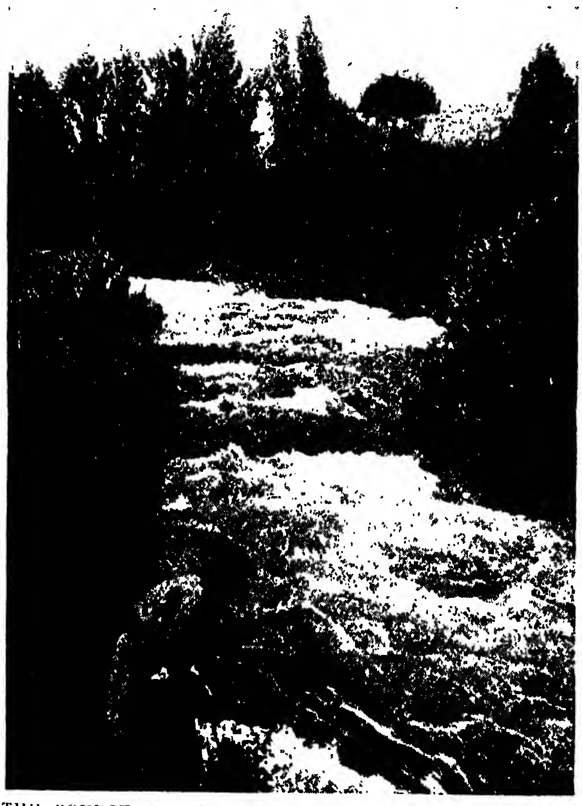
AN ALPINE STOREHOUSE OF THE WATERS



THE ALLALINHORN, SWITZERLAND, WITH AVALANCHE DEBRIS ON THE FEE GLACIER IN THE FOREGROUND

make a world of difference. Again, the "divide" between the basins of the Mississippi and the St. Lawrence decides destinies as different as the courses of these two rivers; and in this case the divide is so low that in times of flood it is possible to pass by canoe from one river to the other. An interesting example of the same division of ways is seen in a street in the village of Chard, in Somerset. In this street the water from one gutter runs into the Bristol Channel, on the west, and from the other into the English Channel, on the south.

We have said that most rivers are originated by rain which trickles and runs into certain channels, but in many cases rivers originate only indirectly in this way; in many instances their source is a spring. The River Dee, in Aberdeenshire, for instance, arises from springs known as the Wells of Dee, and the River Shannon rises from a spring in a meadow known as the "Pot." In other cases, rivers gush out from underground almost fully formed. This is the case with a river that flows into Klamath Lake, in Southern Oregon, and several full-grown streams are said to flow from a base of Kilimanjaro, in an inaccessible region of Central Africa.



THE SOURCE OF THE RIVER JORDAN—A SPRING AT TELL-EL-KADI, OR DAN

The area of country drained by a river is known as its basin, and this area is, of course, delimited and defined by watersheds. The actual course of a river is known as its track, and in a typical river the track may be divided into three parts—the mountain or torrential track, the valley track, and the plain track.

The torrential or mountain track has a slope of fifty feet or more in the mile. Down such steep tracks rivers rush headlong, often at a rate exceeding twenty miles an hour. The torrent of water pouring over a rough bed works much destruction, uprooting trees, rolling down boulders, eroding away rocky or earthy banks, cutting deep ravines in the mountain-side.

The valley track has a slope of up to ten feet per mile, giving a velocity to the stream of up to five miles an hour. A moderate current runs at the rate of one and a quarter miles in the hour. The Thames has a gradient of 21 inches per mile; the Rhône, from Besançon to the Mediterranean, 24·2 inches per mile. In the valley track of its course a river both constructs and destroys; it carries débris from place to place.

Rushing along at eight miles an hour, a stream can displace boulders four feet in diameter; "at two miles an hour stones as large as a hen's egg are rattled along; at one and a third miles an hour the current can just roll pebbles one inch in diameter; when gliding at half a mile an hour, gravel as large as peas is swept forward, while at a quarter of a mile an hour a river cannot disturb fine sand." If the velocity of a river doubles, its transporting power is increased sixty-four times; and if the velocity trebles, its transporting power is increased seven hundred and twenty-nine times. In certain parts of its valley track a river will dislodge stones and gravel, and at other parts, depending on its velocity, will deposit them.

The plain track is the track of the river across level plains which often are formed of its own deposits. In this track its flow is often split, and hemmed, and dammed. Well does Arnold describe this part of the track of the Oxus:

"He flowed
Right for the polar star, past Orgunjè,
Brimming, and bright, and large; then sands begin
To hem his watery march, and dam his streams
And split his currents; that for many a league
The shorn and parcelled Oxus strains along
Through beds of sand and matted rushy isles—
Oxus forgetting the bright speed he had
In his high mountain cradle in Pamere
A foiled circuitous wanderer: till at last
The longed-for dash of waves is heard, and wide
His luminous home of waters opens, bright
And tranquil, from whose floor the new-bath'd stars
Emerge, and shine upon the Aral Sea."

The Rhine, the Rhône, the Danube, the Ganges, the Indus, the Mississippi, the Amazon, the Nile, and the Niger all can be divided into the afore-mentioned tracks. When the slope of a river exceeds ten inches in a mile, or 1 in 6336, it is not navigable without locks. The rate of flow of a river is naturally retarded by irregularities of its bottom; and the layer of water next its bottom, being retarded by friction, moves less rapidly than layers of water towards the centre. When a river is impeded by any obstruction along one bank, it forms a deposit at that point, and swerves round to the opposite bank, which it tends to scoop out. The scooped-out concavity, again, makes the water curve again to the opposite bank, where it repeats the scooping-out process. One curve necessarily leads to another like it, in conformity with the law of the reciprocity of curves. In the middle of its course the Mississippi forms a series of curves so much alike in shape and size that the Indians and earliest colonists used them for the purpose of estimating distances. The larger the stream, the shorter the curve it describes. A brook may make several curves in a single small field, whereas a large river may make a curve of ten or twenty miles, and come back almost to the spot from which it started.

A RIVER ISSUING FROM THE MELTING SNOW IN AN ALPINE VALLEY

Having made a loop, a river not infrequently takes a short cut again across the loop, and thus are produced diverging and converging arms with an island between. Sometimes, having made the short cut, it abandons the loops, which then become a crescentic lake of stagnant water known as a

"cut-off." In the basins of the Amazon, the Ganges, the Rhône, and the Po there are many of these cut-offs. In the basin of the Mississippi they are particularly abundant, and are tenanted by alligators, wildfowl, and garfish. More than once by such a cut-off the Mississippi has shortened its course by about thirty miles, and has left riverside towns miles from its currents. By changing its course it has even altered the boundaries of States. A man might go to sleep in his bed in the State of Mississippi, and waken next morning to find himself in Louisiana; or, in the old days of slavery, a slave might go to bed in Missouri, and waken a free man in Illinois. Nor is it in America alone that the rivers play such geographical pranks. The Tweed has more than once, by altering its course, transferred farms from Northumberland into Berwickshire; that is to say, from England into Scotland.

A river famous for its vagaries is the Po, which, in some parts of its course, "only takes about thirty years in forming and destroying each of its meanders."

The Hoang-ho, or Yellow River, in China, has often changed its course, and sometimes with such disastrous results that it has been named "China's Sorrow." In 1887 this river broke through its embankment, and submerged hundreds of villages, drowning more than a million human beings.

THE WINDINGS OF THE FORTH NEAR STIRLING

The result of the winding or meandering of rivers is greatly to extend their course from source to sea. The Scottish Devon meanders for twenty-six miles to cover a distance which is only six and a half miles as the crow flies. The Forth covers twenty miles flowing between Stirling and Alloa, though the distance direct is only seven miles. The Nile, by means of its meanderings, extends its journey by five hundred miles and the Mississippi, between the mouth of the Ohio and the Gulf of Mexico, goes more than twice the distance, measured as the crow flies. These river-meanderings reduce the gradients of rivers and render them more navigable, and they also increase the efficiency of rivers as means of drainage and irrigation.

Many rivers, as is well known, undergo great alterations in the volume of their water. Some rivers, indeed, such as the rivers that sometimes rush down the "barrancas" in Teneriffe, are more often dry than flowing, and most rivers alter in volume from season to season, if not from day to day.

Heavy rainfalls and melting snow necessarily augment the volume of any river they reach, but the augmentation is not nearly so great as at first sight one would expect it to be, since by no means all the rainfall or snowfall goes to increase the bulk of a river. Much sinks into the soil and never reaches the river; much is evaporated; much is given away by the river to any thirsty land it waters. The Thames, for instance, at Staines, has a mean annual discharge equal to 7·31 inches of rain, which is less than a third of the total rainfall. The Elbe probably does not carry off more than a quarter of the rainfall of its basin, and the Seine not more than a third of the rainfall of its basin.

But though the volume of rivers is not always augmented in proportion to the rainfall and snowfall of their basins, yet the volumes of all rivers fluctuate to some degree according to their supply of water. Often these fluctuations are very sudden and very great. A mountain stream which may be only a runnel will, on the occasion of the first thaw, be suddenly changed into a river running thirty miles an hour, and big

enough to overspread fields and wash away houses. The Var, for instance, sometimes discharges as little as 37 cubic yards a second, but when in flood discharges no less than 5240 cubic yards a second. Or take the case of the three little streams the Doux, the Erieux, the Ardèche. These are usually little streams, discharging 20 to 25 cubic yards of water a second, but during a flood in 1857 they discharged at the rate of 18,000 cubic yards a second—as much as the discharge under ordinary circumstances of the Euphrates and the Ganges. On this occasion the Ardèche rose to a height of 60 feet above low-water mark. The Rhine is frequently flooded, and sometimes rises 23 feet, and discharges about 20,000 cubic yards of water a second. If all its mountain tributaries were in flood at once it would become a second Amazon, and would discharge more than 130,000 cubic yards of water a second. The Seine has been known to rise 20 feet, the Saône 24½ feet, and the Danube 60 feet above low-water level.

In tropical regions the rivers of medium size are usually dry half the year and in flood half the year. All round the Red Sea there is a perfect system of river-beds, but except during the season of the rains there is no water. One of these dried-up rivers, the Roumah, is 750 miles in length.

In some tropical valleys there are daily fluctuations owing to daily storms. "In the evening all the gorges are filled with masses of raging water; and the traveller finds himself compelled to put a stop to his journey. He bivouacs on the edge of the river, and is lulled to sleep by the noise of the cataracts roaring over the rocks, but when he wakens at dawn next day all he sees is a slender rivulet of water, only visible here and there among the masses of gravel."

The fluctuations in volume of the Amazon are peculiar. This great river receives tributaries both from the northern and the southern hemisphere. The northern tributaries are in flood in summer and autumn, and the southern tributaries in winter, and so the level of the water in the Father of Waters is kept high and pretty constantly in flood. The overflowing of the Amazon is a deluge rather than an overflow, for in places it makes a sea wide enough to cover most of England.

"The great river was terrible to look upon," writes Herndon, the American traveller, "as it rolled through the solitudes with a solemn and majestic air. Its waters seemed to wear a wrathful, malevolent, and pitiless aspect. The entire landscape had the effect of stirring up in the mind a feeling of horror and dread similar to that produced by the imposing solemnities of a funeral at sea, by the minute-gun firing at intervals, the howling of the tempest and the wild uproar of the waves, when the crew assemble on the deck to bury their dead in the bosom of a troubled sea."

In former days the Mississippi was subject to floods resulting in great overflows, but much has been done in recent time to confine the river between embankments. The Ganges too, has its flood, and every April converts the plain through which it flows into a lake 32 feet deep.

The most celebrated floods in the world are probably the periodic floods of the Nile,

THE DEVASTATING FLOODS IN THE VALLEY OF THE MISSISSIPPI

which irrigate and fertilise the land of Egypt. All of a sudden in dry, sunny weather the Nile rises, and continues to rise till at its highest its volume is increased ten or twenty fold. To the ancients the rise was a prodigy and a marvel, but we now know that the rise is due to rains and thawing snows on the Abyssinian mountains of the upper reaches of the Nile.

As is well known, rivers vary in colour, and sometimes by their colour they have been named. Thus, the Greeks have a River Aspropotamo, or White River, and there are many Rio Blancos, while a certain stretch of the Nile is known as the White Nile. There is also in America the Rio Colorado, or Red River, and in China the Hoang-ho, or Yellow River; while in Scotland there is the Blackadder, and in Masailand the Black River. It may be noted here, however, that the word "Orange" in "Orange River" refers to the House of Orange and not to the colour of the river, and that the Niger is not so called because black, but because "N-eg-hirren" is the native word for "river."

In some cases the colour of a river is due to the colour of its bottom or of its reflected banks. Thus, the Black River of Masailand appears black because of the black lava over which it flows. In other cases it is the contents of the river, such as clay or peat, that give the river its characteristic colour. Thus, the Blackadder is blackened by its peaty contents: and there is an inky-black stream in Algeria whose waters are really black owing to the fact that one of its two tributaries absorbs iron from the soil, while the other absorbs gallic acid, the mixture of the two accordingly producing actual ink. Rivers vary also in taste according to the mineral ingredients they contain. Some are actually salt, like the Salt River of Australia, and some are acid, like the Rio de Vinagre, in Central America.

When we look in a general way at the distribution of rivers one of the first things that strikes us is that the distribution is unequal, and that the Atlantic receives more than its fair share of river water. Into the Atlantic flow almost all the great rivers of the world—the Amazon, the Mississippi, the Orinoco, the St. Lawrence, the Paraguay, the Paraná, the Congo, the Niger, the Gambia, the Danube, and the Nile. Into the Pacific flow only five big rivers—the Hoang-ho, the Mekhong, the Yangtse-kiang, the Amur, and the Columbia.

A RIVER IN MINIATURE

This rivulet, like the giant rivers, winds its way to the sea, wearing its path through the softest parts of the soil.

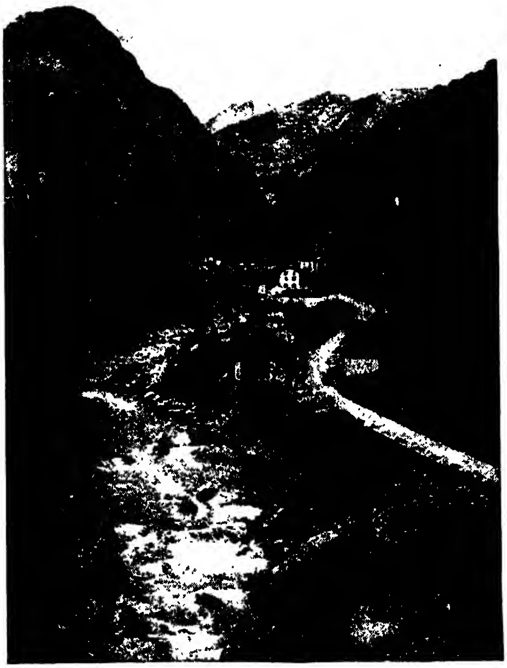
Looking at the continental distribution of rivers, we find that Asia has three great rivers running northward across the great plain of Siberia, and four pairs of great rivers running southward. The three great Siberian rivers are the Ob, the Lena, and the Yenisei. The four pairs of great southward rivers are the Tigris and Euphrates, flowing into the Persian Gulf; the Ganges and Brahmaputra, into the Bay of Bengal; the Indus and Sutlej, into the Arabian Sea; and the Hoang-ho and Yangtse-kiang, flowing into the Pacific Ocean. The Tigris and Euphrates and the Indus and Sutlej unite at considerable distances from their mouths, but in the greater parts of their courses they are separate rivers.

Europe has two river systems—a system of great rivers, the Volga, the Dwina, the Niemen, the Bug, and the Dnieper, which rise in marshy ground in the centre of Russia; and a system of great rivers, the Rhine, the Rhône, the Danube, the Ticino, which take their rise in the heart of the highest mountains. It is noticeable that the four last-mentioned rivers each reach a different sea: the Rhine enters the North Sea; the Rhône, the Mediterranean; the Danube, the Black Sea; and the Ticino, the Adriatic.

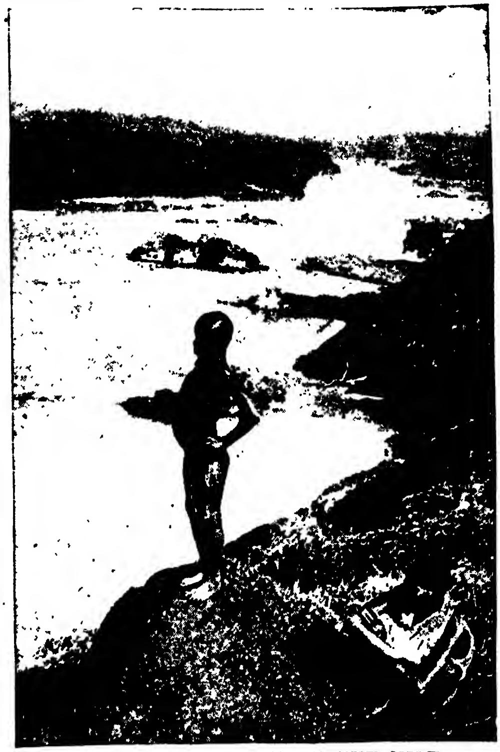
Africa has several great rivers—the Nile, the Niger, the Congo, the Zambesi, the Orange River, the Limpopo. All these arise from the centre of the continent, but at great distances from each other, and all run comparatively straight courses and have few tributaries. The Nile flows into the Mediterranean, the Niger and Congo into the Atlantic, and the Zambesi, Limpopo and Orange River into the Indian Ocean.

In Australia the only considerable rivers are the Murray, and its tributary, the

IN SEARCH OF THE PEACE OF THE PLAINS

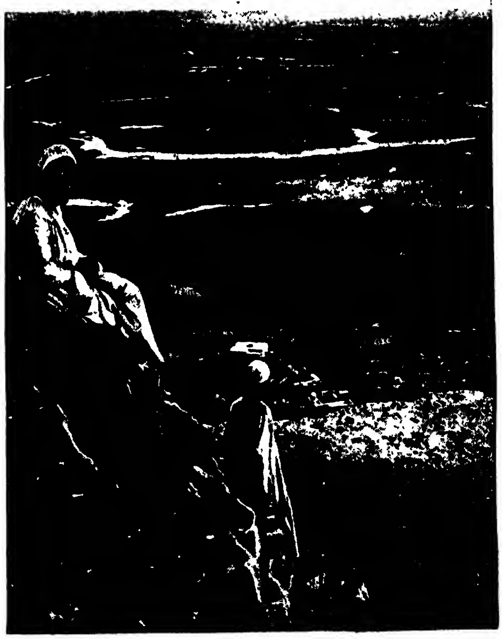


THE TICINO AS A MOUNTAIN TORRENT



THE UPPER REACHES OF THE NILE

THE UPPER VALLEY OF THE DANUBE CUT THROUGH THE BAVARIAN MOUNTAINS



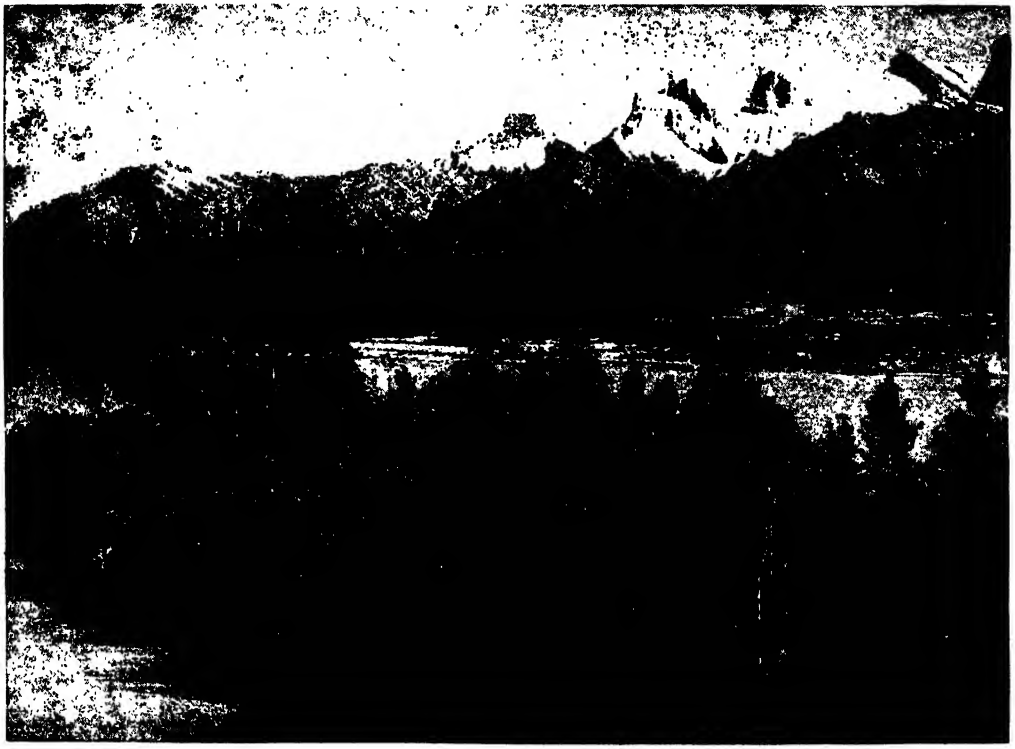
THE NILE VALLEY JUST AFTER INUNDATION, VIEWED FROM THE GREAT PYRAMID

Darling. Most of the other rivers flood in the rainy season, and are almost entirely dried up in the dry season.

In North America there are two river systems arising from mountain ranges, and a third intermediate river system rising from an elevated plain. From the Union Peak range, in Idaho, radiate the Missouri, the Colorado, and the Rio Grande del Norte. Further north, from the Murchison range, rise the Fraser River, the Columbia, the Saskatchewan, the Athabasca, and the Mackenzie; while between these two groups, from a plain situated to the west of Lake Superior, spring the Northern Red River, the Mississippi, and the St. Lawrence.

Of all the continents South America can display the greatest rivers, for it owns the Amazon, the Paraná, and the Orinoco, while some of the tributaries of the Amazon and Paraná are themselves huge rivers. The Amazon and the Orinoco arise in the Andes; the Paraná arises from a high plateau in the interior of Brazil, and all three rivers communicate by tributaries, so that there is a continuous network of water from the north of the continent almost to the south. The Paraná joins the Paraguay to form the estuary known as the Rio de la Plata.

It is a remarkable fact that the basin of the Amazon is the gentlest landslope in the world; even at a distance of 1900 miles from the sea it attains an elevation of only 600 feet. Its average gradient, therefore, for that distance is less than four inches in the mile, a decline so slight as to emphasise greatly the dimensions of the river, for, notwithstanding this leisurely flow, the volume of water discharged is enormously larger than that of any other river.



A RIVER VALLEY BELOW THE MOUNTAINS—THE BOW RIVER, ALBERTA

The following table, collated by H. R. Mill, draws some interesting comparisons between some of the world's great rivers.

River	Area. of Basin. Square Miles	Rainfall of Basin. Cubic Miles	Average Annual Discharge. Cubic Miles	Length in Miles
Amazon ..	2,230,000	2834	528	3060
Congo ..	1,540,000	1213	419	2900
Nile	1,290,000	892	24	4000
Mississippi	1,285,000	673	126	4200
La Plata ..	995,000	905	189	2000

A GREAT LIVING LEADER

The Work of Dr. Bateson, the Master and Founder of the School of Genetics

THE ANALYSIS OF FORMATIVE UNITS

In our study of heredity we have found our science so young and so rapidly developing that it was best to deal with it under the names of a few great students; and, having discussed in turn the work of Galton, Weismann, Mendel, and De Vries, we come now to the figure of the contemporary leader in this fertile and almost virgin field of science. Professor William Bateson, F.R.S., was the first holder of the Chair of Biology lately established at Cambridge in honour of Darwin. He retired from that chair in order to have more time for research, and became director of the John Innes Horticultural Institution at Merton, in Surrey, and later Professor of Physiology at the Royal Institution.

Professor Bateson is now the leader of the Mendelian school, the present achievements of which will afterwards, and for long afterwards, concern us. But his preparation for this study began earlier than the present century, and requires our understanding here. We must go back nearly twenty years, to the publication of his great book, now looked upon as a classic by biologists, which is modestly entitled "Materials for the Study of Variation," and which was published in 1894. The title is modest indeed, but if we think a moment we shall see that it conveys rather more than meets the ear. In fact, it is "a summons and a challenge."

When it appeared, biologists were, for the most part, in a somewhat hypnotic, not to say cataleptic, state, under the influence of Darwin. Herbert Spencer was protesting against the uncritical acceptance of "the all-sufficiency of natural selection," but, as he held no degree and had never passed an examination, of course his observations could be discounted. Hence the title of Dr. Bateson's book was startling, for it seemed to suggest what we now see to be so exceedingly true—that the study of variation had at that time practically not even begun, and that the first necessity was for the collection of exact facts. What this meant and means for Darwinism, or for any other special theory of organic evolution, we can see at once, if we remember that variations are the very material and essential of all evolution, and that, in reality, the study of evolution is the study of variations. Everyone was supposing that evolution had been explained, once and for all. Darwin's remains were in the Abbey, and then there appeared this book, which suggested that, in time, we might be ready to begin at the beginning.

When the natural selection of minute chance variations of living creatures is felt to be an inadequate explanation of the facts of living nature, we ask ourselves or, rather, Dr. Bateson asked himself whether there are not other kinds of variation, that do occur not infrequently, and that might far more probably furnish the beginnings of new species. The conclusion to which he came is that there are two distinct kinds of variation, to which he gave the name of continuous and discontinuous variation respectively. The former is universal and illustrated by every living creature, and it is this type of variation in which the theory of Darwin sees the material for natural selection to act upon. But the conclusion to which Dr. Bateson came, as long ago as 1894, was that the very grave difficulties in the way of accepting this theory may be avoided if we turn to the facts of discontinuous variation. In sum, he showed "(1) that differences of the kind which are generally used to distinguish separate species may arise as single variations; (2) that such a form of variation is by no means so uncommon a phenomenon as was formerly supposed; and (3) that

variations of this kind may occur in every description of organ and part, in a number of different plants and animals."

We see at once, of course, that there is a substantial identity between the view of Bateson, that organic evolution depends upon discontinuous variations, and the "mutations theory" of De Vries, which we have already studied. And naturally an author who had already come to these conclusions was prepared for the rediscovery of Mendel's paper half a dozen years later. He saw at once that we now required an experimental science, which should begin at the beginning, and try to ascertain the precise facts of heredity and variation, with the aid of the long-lost key which Mendel had provided. Biologists had neglected this essential task. As Dr. Bateson himself says: "Darwin's achievement so far exceeded anything that was thought possible before that what should have been hailed as a long-expected beginning was taken for the completed work. I well remember receiving from one of the most earnest of my seniors the friendly warning that it was waste of time to study variation, for Darwin had swept the field."

Genetics a Contribution to the Advancement of Pure Physiological Science

Nevertheless, Dr. Bateson has founded the science of genetics, primarily "in the hope that it would elucidate the problem of species." But, in the course of a decade or so, the possibilities of these experiments have become greatly extended. Here is Dr. Bateson's own statement: "The time has now come when appeals for the vigorous prosecution of this method should rather be based on other grounds. It is as directly contributing to the advancement of pure physiological science that genetics can present the strongest claim. We have an eye always on the evolution problem. We know that the facts we are collecting will help in its solution, but for a period we shall perhaps do well to direct our search more especially to the immediate problems of genetic physiology, the laws of heredity, the nature of variation, the significance of sex, and other manifestations of dimorphism [i.e., "two-form-ism"], willing to postpone the application of the results to wider problems as a task more suited to a maturer stage. When the magnitude and definiteness of the advances already made in genetics come to be more generally known, it is to be anticipated that workers in various departments of biology will realise that here at last is common ground."

The truth is that experimental breeding is the only way in which we can learn many facts about individuals and their composition and constitution. Genetics was founded, as its name implies, in order to define and study the problems of genesis. But now we discover that in studying these problems we find the clue to all manner of questions which general physiology is interested in. Nothing, for instance, is more interesting for biology in general than the nature of sex.

The Reach of the Science to Consequences Far Beyond the Scope of Heredity Merely

Genetic experiment began by assuming the fact of sex, of course, and proceeding to observe the consequences of bi-sexual reproduction; but it goes on to see that sex itself is a characteristic which may be studied genetically, just like eye-colour. We find that the sex of an individual is one of its features, dependent, like other features, upon certain "factors," or "determinants," in the germ-cells whence it was formed. We learn, too, how strangely this factor of maleness or femaleness affects other characters which are transmitted and represented in the germ-cells beside them, so that if the factor for maleness be present along with the factor which gives rise to what is called the "bleeding disease," the boy will be a "bleeder," but if femaleness and the factor for this disease come together, the girl is *not* a "bleeder," though her sons may be. This is a mere illustration, in passing, to show how entirely the claim of the founder of genetics is justified when he suggests that these inquiries are of interest to far more students than those of heredity alone.

Novel and Invaluable Contributions to the Chemistry of Physiology

One other illustration of his contention may be referred to. There is a department of science called physiological chemistry, which studies the chemistry and chemical interactions of the different parts of living bodies. But this science has hitherto been quite unable to throw any light upon the development of the adult body from the germ, though plainly there must be plenty of chemical problems involved therein. Here genetics, with its new method, and its unprecedented angle of attack upon standing physiological problems, makes novel and invaluable contributions. The study of the inheritance of the colours of sweet-peas, for instance, shows how such and such a colour may be altered into another by the addition of a special

"factor" to the germ-cells. But when we ascertain that the second colour is simply an oxidation product of the first, naturally we surmise that the extra factor in the germ-cells which made the difference must be of the nature of an oxidising ferment. Thus the standing ideas of the architecture of the body and the corresponding architecture of the germ-plasm, so much discussed by Weismann, come to be supplemented by ideas of the chemistry of the body, and the corresponding chemistry of the germ-plasm; and we begin to suspect that these latter ideas are the deeper of the two.

Dr. Bateson's Definition of Genetics—the Physiology of Heredity and Variation

But this is a case where no exposition by others is required, for we have Dr. Bateson's own words to draw upon; and the best service the writer can perform, for the reader and for genetics, is to present in brief, but with some exact citations, the arguments and the conclusions embodied in Dr. Bateson's inaugural lecture as Professor of Biology in the University of Cambridge. That lecture, entitled "The Methods and Scope of Genetics," was delivered late in 1908, and we may consider it now with the confidence and the subsequent knowledge gained in the intervening period. In introducing that lecture Dr. Bateson defines genetics as "the physiology of heredity and variation," and states his belief that "genetic research is still pushing forward in the central undifferentiated trunk of biological science," thanks to "Mendelian discovery leading us into a new world, the very existence of which was unsuspected before."

The Two-Cell Production of all Ordinary Forms of Life, and Its Consequences

We start from the familiar fact that all the ordinary animals and plants begin their individual lives by the union of two cells, the one male, the other female. "Now, obviously the diversity of form which is characteristic of the animal and plant world must be somehow represented in the gametes, since it is they which bring into each organism all that it contains. . . The fact that *two* cells are concerned in the production of all the ordinary forms of life was discovered a long while ago, and has been part of the common stock of elementary knowledge of all educated persons for about half a century. The full consequences of this double nature seem nevertheless to have struck nobody before Mendel. . . . We are accustomed to think of a man, a butterfly, or an apple-tree as each *one* thing. In order to understand the significance of Mendelism we must get thoroughly familiar with the fact that they are each *two* things, double throughout every part of their composition. . . . That we are assemblages or medleys of our parental characteristics is obvious. We all know that a man may have his father's hair, his mother's colour, his father's voice, his mother's insensibility to music, and so on, but that is not enough.

"Such an analysis is true, inasmuch as the various characters *are* transmitted independently, but it misses the essential point. For in each of these respects the individual is double; and so to get a true picture of the composition of the individual we have to think how *each* of the two original gametes was provided in the matter of height, hair, colour, mathematical ability, nail-shape, and the other features that go to make the man we know. The contribution of each gamete in each respect has thus to be separately brought to account."

Pure Breeding and Cross-Breeding According to Germ-Cell Ingredients

"If we could make a list of all the ingredients that go to form a man, and could set out how he is constituted in respect of each of them, it would not suffice to give one column of values for these ingredients, but we must rule two columns, one for the ovum and one for the spermatozoon, which united in fertilisation to form the man, and in each column we must represent how that gamete was supplied in respect of each of the ingredients in our list. When the problem of heredity is thus represented we can hardly avoid discovering, by mere inspection, one of the chief conclusions to which genetic research has led. For it is obvious that the contributions of the male and female gametes may in respect of any of the ingredients be either the same or different. In any case in which the contribution made by the two cells is the same, the resulting organism—in our example the man—is, as we call it, *pure bred* for that ingredient, and in all respects in which the contribution from the two sides of the parentage is dissimilar the resulting organism is *cross-bred*."

We have already learnt that in the Mendelian analysis there occur the terms "dominant" and "recessive" to describe characters which appear or do not appear, characters which are patent or latent in any individual. This contrast is not an essential

part of Mendelism, but it is very notable, and needs explanation. The now accepted view of its cause is called the "presence or absence hypothesis," which was framed by Professor Bateson, and which he describes in the following words:

"We have got to the point of view from which we see the individual made up of a large number of distinct ingredients, contributed from two sources, and in respect of any of them he may have received two similar portions or two dissimilar portions. We shall not go far wrong if we extend and elaborate our illustration thus."

An Illustration of the Theory of Genetic Ingredients

"Let us imagine the contents of a gamete as a fluid made by taking a drop from each of a definite number of bottles in a chest containing tinctures of the several ingredients. There is one such chest from which the male gamete is to be made up, and a similar chest containing a corresponding set of bottles out of which the components of the female gamete are to be taken. But in either chest one or more of the bottles may be empty; then nothing goes in to represent that ingredient from that chest; and if corresponding bottles are empty in both chests, then the individual made on fertilisation by mixing the two collections of drops together does not contain the missing ingredient at all. It follows, therefore, that an individual may thus be 'pure bred'—namely, alike on both sides of his composition—as regards each ingredient in one of two ways, either by having received the ingredient from the male chest and from the female, or in having received it from neither. Conversely, in respect of any ingredient he may be 'cross-bred,' receiving the presence of it from one gamete and the absence of it from another."

The Interplay of Qualities, Present or Absent, in One Parent or Both, a Prime Conception

"The second conception with which we have now to become thoroughly familiar is that of the individual as composed of what we call presences and absences of all the possible ingredients. It is the basis of all progress in genetic analysis. . . . A blue eye is due to the absence of a factor which forms pigment on the front of the iris. Two blue-eyed parents, therefore, as Hurst has proved, do not have dark-eyed children. The dark eye is due to either a single or a double dose of the factor missing from the blue eye. So dark-eyed persons may have families all dark-eyed, or families composed of a mixture of dark and light eyed children in certain proportions which on the average are definite."

Plainly, the reason why the dark-eyed people may have two kinds of families is that the dark or brown eye may be "pure," its possessor having received the presence of the factor from both parents, or "impure," its possessor having received the presence of the factor from one parent and the absence from the other. Brown is dominant over blue because, on Professor Bateson's theory, brown is due to the presence of something the absence of which makes a blue eye; hence, if the brownness comes from one parent and the blueness (which is merely the absence of brownness) from the other, the offspring will have brown eyes, and we say that brown is dominant over blue. The "presence and absence hypothesis" beautifully explains this and a host of similar cases. But we cannot do better than quote Dr. Bateson himself. Having shown the double origin of constitution of the individual, and what it means, he proceeds to the next question:

The Phenomenon which is the Essence of Mendel's Discovery

"So far we have been considering the synthesis of the individual from ingredients brought into him by the two gametes. In the next step of our consideration we reverse the process, and examine how the ingredients of which he was originally compounded are distributed among the gametes that are eventually budded off from him.

"Take first the case of the components in respect of which he is pure bred. Expectation would naturally suggest that all the germ-cells formed from him would be alike in respect of those ingredients, and observation shows, except in the rare cases of originating variations, the causation of which is still obscure, that this expectation is correct. . . . But when we proceed to ask how the germ-cells will be constituted in the case of an individual who is cross-bred in some respect, containing, that is to say, an ingredient from the one side of his parentage and not from the other, the answer is entirely contrary to all the preconceptions which either science or common sense had formed about heredity. For we find definite experimental proof, in nearly all the cases which have been examined, that the germ-cells formed by such individuals do either contain or not contain a representation of the ingredient, just as the original gametes did or did not contain it. If *both* parent-gametes brought a certain quality in, then all the daughter-

gametes have it; if neither brought it in, then none of the daughter-gametes have it. If it came in from one side and not from the other, then on an average in half the resulting gametes it will be present and from half it will be absent. This last phenomenon, which is called segregation, constitutes the essence of Mendel's discovery. . . . It is this fact which entitles us to speak of the purity of germ-cells. They are pure in the possession of an ingredient, or in not possessing it; and the ingredients, or factors, as we generally call them, are units because they are so treated in the process of formation of the new gametes, and because they come out of the process of segregation in the same condition as they went in at fertilisation."

Rules that are Exemplified in Heredity with Remarkable Exactness

"As a consequence of these facts it follows that, however complex may be the origin of two given parents, the composition of the offspring they can produce is limited. There is only a limited number of types to be made by the possible recombinations of the parental ingredients, and the relative numbers in which each type will be represented are often predicable by very simple arithmetical rules. For example, if neither parent possesses a certain factor at all, then none of the offspring will have it. If either parent has two doses of the factor, then all the children will have it; and if either parent has one dose of the factor and the other has none, then on an average half the family will have it and half be without it. . . . In such an observation two things are strikingly exemplified: (1) the fact of the permanence of the unit; and (2) the fact that a *mixture* of types in the family means that one or other parent is cross-bred in some respect, and is giving off gametes of more than one type."

Questions Put to Nature in Her Hidden World of Life's Renewal

"The problem of heredity is thus a problem primarily analytical. We have to detect and enumerate the factors out of which the bodies of animals and plants are built up, and the laws of their distribution among the germ-cells. All the processes of which I have spoken are accomplished by means of cell-divisions, and in the one cell-union which occurs in fertilisation. If we could watch the factors segregating from each other in cell-division, or even if by microscopic examination we could recognise this multitudinous diversity of composition that must certainly exist among the germ-cells of all ordinary individuals, the work of genetics would be much simpler than it is.

"But so far no such direct method of observation has been discovered. In default we are obliged to examine the constitution of the germ-cells by experimental breeding, so contrived that each mating shall test the composition of an individual in one or more chosen respects, and, so to speak, sample its germ-cells by counting the number of each kind of offspring which it can produce. But cumbersome as this method must necessarily be, it enables us to put questions to Nature which never have been put before. She, it has been said, is an unwilling witness. Our questions must be shaped in such a way that the only possible answer is a direct Yes or a direct No. By putting such questions we have received some astonishing answers which go far below the surface. Amazing though they be, they are nevertheless true; for though our witness may prevaricate, she cannot lie. Piecing these answers together, getting one hint from this experiment, and another from that, we begin little by little to reconstruct what is going on in that hidden world of gametes."

The Complexity of the Arrangements by which Some Qualities are Produced

Very early in these studies we discover that by no means all the characteristics of living creatures are due to the presence or absence of a single factor from their constitution. There are many features which require the concurrence of several factors to produce them; nevertheless, though the character only appears when all the complementary ingredients are together present, each of these severally and independently follows, as regards its transmission, the simple rules already described. Thus, for instance, there are two dwarf varieties of sweet-pea, the "Cupid" and the "bush," which, when crossed together, yield offspring of full height. As Professor Bateson says, "There is thus some element in the Cupid which, when it meets the complementary element from the bush, produces the characteristic length of the ordinary sweet-pea. We may note in passing that such a fact demonstrates at once the nature of variation and reversion. The reversion occurs because the two factors that make the *height* of the old sweet-pea again come together after being parted; and the variations by which each of the dwarfs came into existence must have taken place by the dropping out of one of these elements or of the other."

But the various Mendelian factors may have other mutual relations. The presence of one will often prevent or inhibit the development and appearance of another. Thus the factor for sex may prevent the appearance of certain characters, say in a female, though the factors for those characters are also present. Or, again, all the factors for the production of colour may be present in a plant or an animal, but there may be a further factor present which keeps the individual white. If that one factor can be bred out, then the colour will appear. Again, to quote Bateson :

" There are cases in which the action of factors is superposed one on top of the other, and not until each factor is removed in turn can the effects of the underlying factors be perceived. So in the mouse, if no other colour-factor is present, the fur is chocolate. If the next factor in the series be there, it is black. If still another factor be added, it has the brownish-grey of the common wild mouse. Conversely, by the variation which dropped out the top factor, a black mouse came into existence. By the loss of the black factor, the chocolate mouse was created, and, for aught we can tell, there may be more possibilities hidden beneath."

The Repulsions as well as Attractions that Exist Among the Genetic Ingredients

Similarly, experiment shows that in many instances there is an antagonism or repulsion between certain factors, so that if one of them goes into a germ-cell, the other never does, and thus an individual having the combination of the two characters in question cannot exist. This is illustrated in such organisms as sweet-peas, but it is also capable of illustration in the almost innumerable types of human nature. Human abnormalities, also, such as colour-blindness, illustrate a further possibility. This condition is apparently due to the presence of some positive ingredient which affects the sight. " Just as nicotine poisoning can paralyse the colour-sense, so may we conceive the development of a secretion in the body which has a similar action." But the general rule is that women do not suffer from colour-blindness, though they may have colour-blind sons. It seems that in a woman there is a positive factor which counteracts the colour-blindness factor, though that is present, and the counteracting factor is probably the femaleness factor itself.

Such a survey of the " Methods and Scope of Genetics " clearly shows that this new science has a bearing on the problem of evolution, and we cannot serve the reader better than by quoting the final paragraphs of this remarkable lecture of Professor Bateson, in which the importance of his work and that of his school for the science of life in general is asserted moderately but convincingly :

The Results of Genetic Research so Novel as to Require Time for Interpretation

" The facts of heredity and variation are the materials out of which all theories of evolution are constructed. At last by genetic methods we are beginning to obtain such facts of unimpeachable quality, and free from the flaws that were inevitable in older collections. From a survey of these materials we see something of the changes which will have to be made in the orthodox edifice to admit of their incorporation, but he must be rash indeed who would now attempt a comprehensive reconstruction. The results of genetic research are so bewilderingly novel, that we need time and an exhaustive study of their inter-relations before we can hope to see them in proper value and perspective. . . . We cannot think yet of interpreting these complex phenomena in terms of a common plan. All that we know is that there is now open for our scrutiny a world of varied, orderly, and specific physiological wonders into which we have as yet only peeped. To lay down positive propositions as to the origin and inter-relation of species in general now would be a task as fruitless as that of a chemist must have been who had tried to state the relationship of the elements before their properties had been investigated."

Evolution Not a Problem at Large, but One of Critical Analysis

" For the first time *variation* and *reversion* have a concrete, palpable meaning. Hitherto they have stood by in all evolutionary debates, convenient genii, ready to perform as little or as much as might be desired by the conjurer. That vaporous stage of their existence is over, and we see variation shaping itself as a definite, physiological element, the addition or omission of one or more definite elements ; and reversion as that particular addition or subtraction which brings the total of the elements back to something it had been before in the history of the race."

" The time for discussion of evolution as a problem at large is closed. We face the problem now as one soluble by minute, critical analysis. Lord Acton, in his inaugural lecture, said that in the study of history we are at the beginning of the

documentary age. No one will charge me with disrespect to the great name we commemorate this year if I apply those words to the history of evolution. Darwin it was who first showed us that the species have a history that can be read at all. If in the new reading of that history there be found departures from the text laid down in his first recension, it is not to his fearless spirit that they will bring dismay."

The Organism a Living Mosaic, Made Up of a Vast Number of Units

Such was the position of genetics as stated by its founder in 1908. Very great developments have occurred since then, by the use of the key and the methods provided by Mendel. We shall observe that, in one of the preceding quotations, Professor Bateson excepts the case of what he calls "originating variations"—*i.e.*, actual novelties appearing for the first time in the history of the species. They remain the question of questions, and we must beware of supposing that Mendelism, or contemporary genetics, can solve it. Later we shall see what hope there is of contributing to its solution by specially devised experiments. Meanwhile, we have to deal with a theory, and a method, which gives us the key to the transmission, the combinations, the partings and recombinations of characters already existing.

Our present business is enormously to extend the range of facts which this key will enable us to ascertain. It gives us the idea of a living creature as a living mosaic, made up of vast number of definite, characteristic units, which may be arranged and combined in many patterns. We have to analyse as many living creatures as possible, so as to define their mosaic constitution; and we see that the method of experimental breeding will reveal what the knife and the dissecting-table are quite inept for. Nothing but the genetic method could tell us that under the black coat of a mouse there is a chocolate coat, if the factor for blackness were not there to conceal it.

The Genetic Problem of the Couplings and Repulsions of the Formative Units

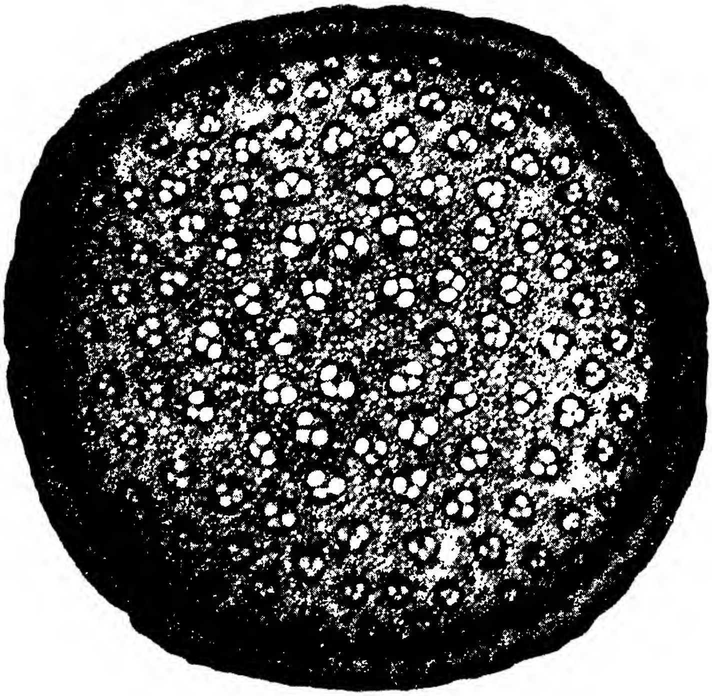
Only the genetic method can show us how the couplings and repulsions and complementary action of different factors affect the constitution and characteristics of living things. Only the genetic method gives us the key to all those forms of true variation which depend upon different shufflings and distributions of the factors in the germ-cells. Only the genetic method will enable us really to appreciate the influence of environment upon the development of the living creature, for until we know its natural possibilities we cannot estimate the action of nurture upon it.

Similarly, such terms as reversion, atavism, "throw-backs," "skipping a generation," and many besides, which have darkened counsel for decades, are being given a real meaning by genetics. We see that when two modern fancy pigeons are mated, and the offspring revert to the characteristics of the ancestral rock-pigeon, nothing more mysterious has happened than the coming together again of factors which were together in the ancestral form, but had been parted in the modern varieties. That is the simple and efficient explanation of true reversion. Other cases of so-called reversion, like feeble-mindedness in mankind, have been analysed by the genetic method, and found to have nothing to do with reversion at all, but to be due to the absence of certain factors which condition the proper development of the nervous system, and which obey the laws of genetics in their transmission.

The Unparalleled Development of Genetics as a Branch of Science

The rapidity of development in this branch of science is almost unparalleled, so efficient are a sound method and a sound theory. New researches are published every week, and the number of workers rapidly increases as men find how fertile this field is compared with such sterile stuff as the academic discussion of "natural selection." In the next chapter we must try to state, as nearly as possible, the established achievements of genetics at the present time. We shall find them substantial and suggestive; but we may as well warn ourselves against the supposition that any of these most recent elaborations of Mendelism throw a light upon the problem of problems, to which Professor Bateson can scarcely be said to have given adequate prominence in the lecture from which we have quoted. He indicates for us the essential discovery upon which his school is based, and qualifies his proposition by the words, "except in the rare cases of originating variations, the causation of which is still obscure." Let us duly note that these "originating variations," as Professor Bateson calls them, are the *sole material* of organic evolution, and that if he had described their causation as still utterly incomprehensible to mechanical science, instead of as merely "obscure," he would still more accurately have stated the limitations even of our newest knowledge.

A CONTRAST IN THE STRUCTURE OF STEMS



THE SCATTERED VASCULAR BUNDLES IN THE STEM OF A MONOCOTYLEDON—SARSAPARILLA

THE ENCIRCLING VASCULAR BUNDLES IN THE STEM OF A DICOTYLEDON—BEECH

The photographs on these pages are by Mr. J. J. Ward and Messrs. Hinkins & Son.

A PLANT'S LIFE-PROCESSES

Buds and Leaves—Their Structure, Development, Action, and Uses

HOW A PLANT FEEDS AND BREATHES

Up to this point in our study of the physiology of plant nutrition, we have been chiefly concerned with that source of the food supply of the plant derived from the various constituents in the soil in which the plant is growing. We have noted what these constituents were, how they came to assume such a form that the plant could utilise them, and how the plant itself managed to extract them from the soil, and transfer them into its own tissue cells. The organs of the plant concerned in this part of the process of nutrition were, as we have seen, the various forms of roots and their appendages, these, taken together, constituting the whole root system of the plant in question.

The absorption from the soil of all these various food supplies, by means of the root, provided nourishment not merely for the immediate needs of the developing young plant, but also, by means of the immense and varied arrangement which different plants develop, enabled in most cases a considerable supply of surplus food to be stored up, either in the seedling, for the benefit of the young embryo, or in special forms of underground stems, for the purpose of enabling a plant to live for a winter period, and to start vigorous growth in the spring. Or this food may remain actually in the stem of the plant itself for purposes of general nutrition.

But there is a second function in plant nutrition which is just as important as is that carried out by the root system, and that is the function of breathing, or respiration; and the study of this aspect of plant life brings us to the question of the buds and leaves of plants.

A close examination of a growing young stem will show the presence upon it of a number of bud-scales, having different positions and arrangements with reference to each other in different species. This can be best noticed just before the leaves begin to appear, because the early stage of a leaf is found in the bud. An examination of a series of these bud-scales gives a complete picture of all the stages between the bud-scales and the perfect leaf. These buds may be distinguished as either lateral or terminal, according to their position on the stem. Some are termed winter buds, these being capable of living throughout the whole of the cold weather on account of their scaly nature, while others are naked buds, having no special protective scaly covering. Such naked buds are those seen on the common geraniums. The original terminal bud of a plant is, of course, the plumule itself. Most of the lateral buds are to be found in the angle formed by the stem and the stalk of a leaf, and such buds are termed axillary in position. Buds other than axillary ones are often referred to as accessory.

As a matter of fact, the term "bud" itself may imply almost any part of a plant which is in an undeveloped stage, the bud merely being a promise of something to come; so that we may regard buds as being either leaf-buds, or flower-buds, or mixed buds, the last being those which contain both leaves and flowers as yet undeveloped.

The most perfect example of the general structure and arrangement of a typical bud is to be found in plants with a large terminal bud, such, for example, as a small cabbage, especially of the red variety, where the parts are condensed closely together, showing their arrangement one to the other. If the head of such a plant be cut longitudinally, we observe a short, thick stem with a large number of closely packed leaves arising from it (the outer ones being the older), and then a number of axillary buds lying in the angle between these leaves and the stem.

At a later stage in growth the arrangement of the leaves themselves can be better seen, and this arrangement differs in different plants. It is termed the vernation of the plant The following examples of differing vernation may be noted: in the cherry, the leaf has its two halves folded flatly together in contact, the young surface being external. In the walnut the separate parts of the leaf (the leaflets, as we may term them) are folded flat into a conical arrangement. In the wood-sorrel the three leaflets of which the leaf is composed are folded smoothly together. In other plants there is a fan-like arrangement. This type of vernation may be best realised by a glance at the illustration in this chapter.

The object of all the different leaf arrangements or vernations is at least twofold. In the first place, economy of space has to be studied in the young plant, and the leaves are therefore packed as closely together as can be conveniently managed. In the second place, it must be remembered that on their first appearance the young leaves are extremely soft and delicate structures, and are unable literally to stand up for themselves until they attain such a growth as involves firmness in their texture. They must therefore be protected both from heat and dryness until they are able to assume the vertical attitude on their own behalf, otherwise they would wither under the heat of the sun at midday. Protection also must be afforded as far as possible from the attacks of insect and parasitic growths; and this is frequently furnished either by a superficial covering of a soft, downy nature or by a special scaly covering.

FAN-LIKE VERNATION OF BEECH LEAVES

ADVENTITIOUS BUDS ON CLIPPED LAUREL

Buds which occur neither at the terminal portion of the stem, nor in the axils of the leaves, are termed adventitious. Good examples of such buds are seen when plants are injured, either intentionally or accidentally, as, for example, when they are cut back, a proceeding which causes buds to develop in positions where otherwise there would be none. In other cases the terminal bud does not appear at all, as in the lilac, and the result of this is seen in the complicated branch of the plant.

So that, to summarise, we find that buds are composed of coverings and the contents within, the latter being either leaf-buds, flower-buds, or mixed buds; and the position of any of these may be normal or abnormal.

Now let us turn our attention to the study of the leaf itself, a structure to which botanists have devoted great attention, partly because the leaf offers a basis for classification and identification. The result is that a great number of technical botanical terms are in use to describe the general and minute structure of leaves. As regards their outlines in general there is immense variation; thus, the whole leaf may be heart-shaped, arrow-shaped, almost round, elongated, much divided, and so forth. Similar variation is seen in the nature of its margin, which is described as being finely serrate, coarsely serrate, doubly serrate, dentate, wavy, crenate, etc.

Then the veins in the leaves, which are very important structures, also exhibit

considerable variation in their arrangement, but in every case adapted so as to give the chief support to such portions of the leaf as need it most; and it may be also noted that the arrangement of the leaves, with reference to the stem, has some general relationship to the shape of the leaf and the arrangement of the veins. Thus, the elongated leaves frequently show the veins running through them in a more or less parallel direction—either running from one end of the leaf to the other, or coming off from the midrib and running in parallel lines to the margin of the leaf. Such plants as the lilies, the grasses, and the sedges all exhibit leaves with parallel veins. In other cases the arrangement of the veins in a leaf suggests a distinct network; and it is a curious fact that this network arrangement is found in plants which have two cotyledons.

When the leaf seems to consist of one single piece, it is referred to as a simple leaf; when, on the other hand, it is doubly cut in two, as in the dandelion, it is spoken of as runcinate, or divided But sometimes the leaf is not a simple one at all, but what is described as compound, when the midrib appears to carry what, at first sight, look like a number of separate leaves, but in reality are divisions of one. The horse-chestnut is an example of a plant bearing a compound leaf, the portions of which do not all wither at the same time. Whether such a leaf is to be regarded as a simple or a compound one may be tested by the presence or absence of buds in the axil, amongst other things.

HAIRY BUD OF BEGONIA

SCALY BEECH-BUD

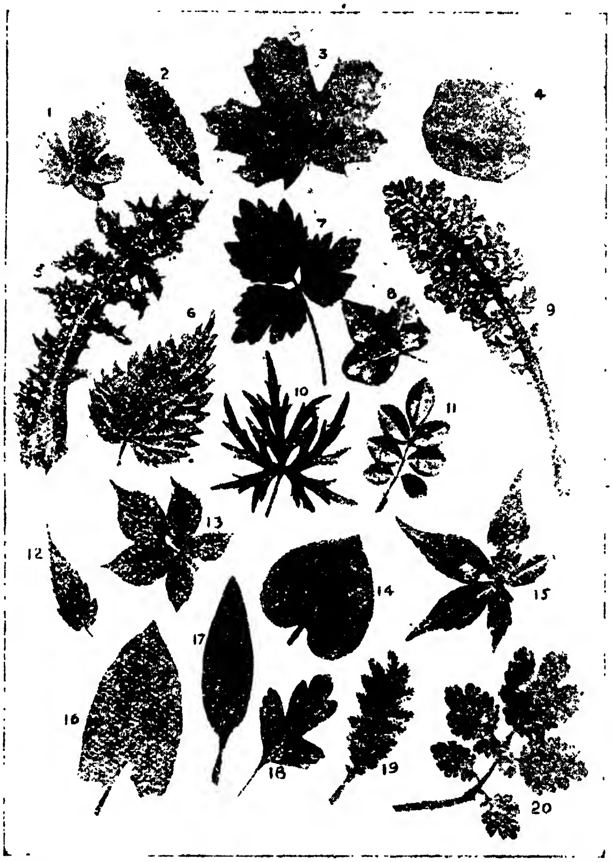
DOWNY BUD OF LUPIN

It will be necessary at this stage, before taking up the detailed consideration of the physiology of roots, stems, and leaves, to say a few words in connection with their anatomical structure, with especial reference to the diagrams and illustrations in this section of our work. If we examine the stem of a dicotyledon we find that most of it is made up of somewhat soft tissue, with some tougher strands running through it. These latter constitute those very important elements in plants known as vascular bundles. These bundles have two functions – first, that of a circulation which distributes the sap to the different parts of the plant; secondly, they act partly as a skeleton, giving firmness and support. On the outside of the skin of the stem is a layer of cells, called here, as in animals, the epidermis. All the rest of the tissue, in such a simple stem, consists of what is termed ground tissue. The vascular bundles are seen to be arranged in a circle; and that part of the stem which is enclosed in this circle is the medulla, or pith, while the part outside the vascular bundle of the circle is the cortex. The narrow portions of tissue running between the bundles connecting the pith with the cortex are the medullary rays.

The epidermis of such a plant is usually found to consist of a single layer of cells. Its function is protective from weather and injuries, and also it hinders the too rapid loss of moisture. Here and there among the cells of the epidermis, openings are found, that are called stomata. On

many leaves, and on some stems, the peculiar and beautiful appearance known as the bloom may be seen; and this is in reality a waxy secretion produced by the cells of the epidermis. Where it exists the loss from water is less than it is at other parts, and it possibly also assists in warding off insects and moulds. The epidermic cells do not usually contain the green colouring matter found in leaves, but instead frequently contain colouring matters of a reddish or purple colour. In addition the epidermis frequently is covered with hairs which are really modified cells and protect the stem from insects. Other hairs act as glands and produce oily or sticky substances, which are also protective.

A transverse section of a vascular bundle taken from the stem of a herbaceous plant shows that it is composed of (1) wood, or xylem; (2) bast, or phloem; and (3) cambium. The details of these different parts are shown in some of our illustrations.



SIMPLE, DIVIDED, AND COMPOUND LEAVES, SHOWING VARIATION OF LEAF MARGINS

1, maple; 2, thistle; 3, plane-tree; 4, nasturtium; 5, sow-thistle; 6, stinging nettle; 7, buttercup; 8, ivy; 9, ragwort; 10, buttercup; 11, rose; 12, kerria; 13, blackberry; 14, aristolochia; 15, Virginian creeper; 16, bindweed; 17, alstromeria; 18, hawthorn; 19, silver weed; 20, greater celandine.

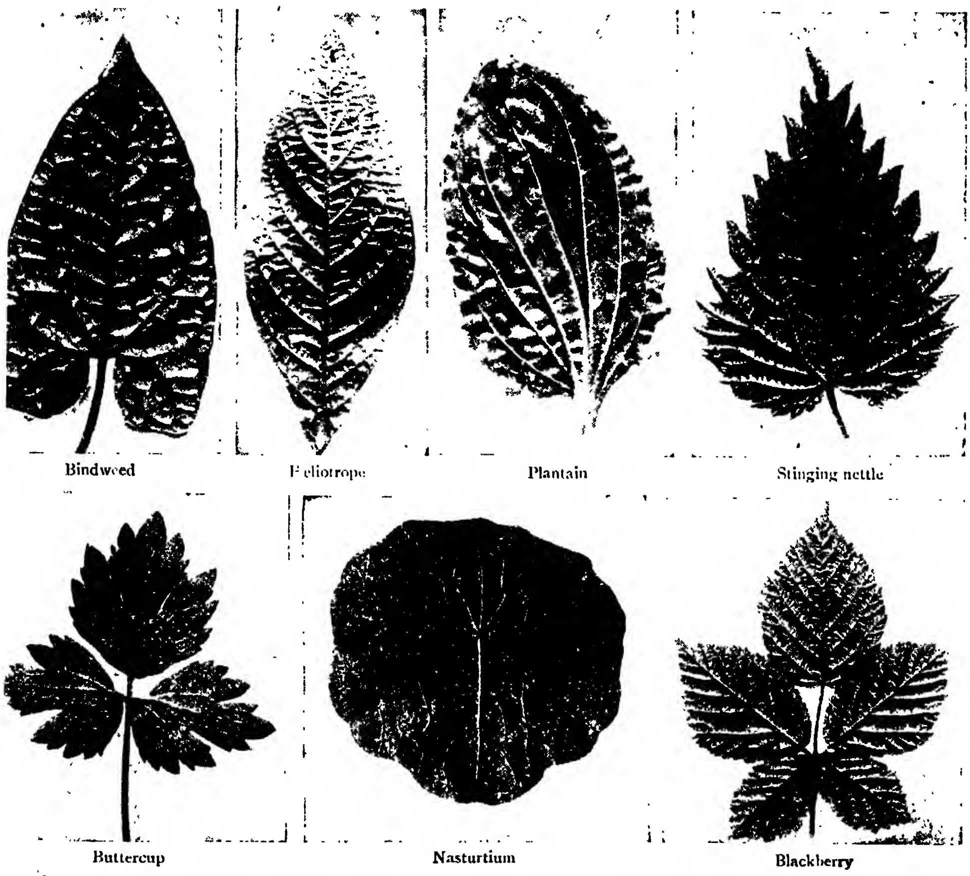
If we compare with the above the stem of a monocotyledon we find a somewhat different arrangement of the vascular bundles. They are no longer found in a single ring, but are scattered through the ground tissue. The result is that the pith, or medulla, is not seen so distinctly, and the cortex is very narrow. In both these, and in the dicotyledons, the vascular bundles are continuous from the stem to the leaf.

Next, as to the minute structure of the leaf itself. It is made up of precisely the same elements as are both stems and roots; that is to say, it consists of a ground tissue in which run the vascular bundles, the whole being covered externally by epidermis. The vascular bundles in a leaf of a dicotyledon branch so as to form a network, which is both a means of sap circulation and also a supporting framework. In a monocotyledon, on the other hand, the vascular bundles as a rule run parallel, and in the body of the leaf. The epidermis, here as in the stem, consists of a single layer of cells whose outer walls are protective, and which are continuous with the epidermis of the stem. Here, too, are stomata, as in the stem, each stoma consisting of two curiously shaped cells, termed guard-cells, placed in contact with each other so as to leave an aperture into an air-chamber within. These stomata are organs of very great importance, since they allow of the moisture escaping from the leaf in transpiration, and in addition play an important part in the exchange of gases between the plant and the atmosphere—that is to say, in the function of respiration.

The ground tissue in the leaf, which is continuous with that of the cortex, is usually divided into two parts—that immediately under the epidermis of the upper aspect of the leaf, and the other portion which lies between the lower layers of epidermis. In this ground tissue in the leaf is found the green colouring matter, or

lorophyll. An examination of the upper rface of most green leaves will show that e green colour is rather deeper on that le than on the under surface. This is cause the chlorophyll is more dense in e upper cells, which themselves are cked closely together.

Now we are in a position to turn our tention in greater detail to the actual rformance of the functions which these uctures carry out on behalf of the plant. l land-plants that are alive are con-



EXAMPLES OF VENATION IN VARIOUS TYPES OF LEAVES

nuously giving off from themselves a rtain amount of water in a vaporous ndition. This process is called tran-iration, and is something quite different om the giving off of water from a wet oth hung out to dry. The latter is a ere question of evaporation. The tran-iration of a plant, however, is a living ysiological function, controlled by the ll protoplasm. The actual quantity of oisture thus given off by transpiration is been measured for some plants, and stated to be twenty ounces in twelve hours for a sunflower three and a half feet high. A cabbage in the same time transpired fifteen ounces. These rather large quantities show that a crop of cabbages would drain from an acre of land several tons of water per day; and as this must come from the water in the soil it is obvious that such soil, having upon it a heavy crop, will tend to dry up quickly.

The process of transpiration varies with the kind of cells on the outside of the leaf, the covering of hairs if present, and to a certain extent with the external atmospherical conditions. Plants with thick outer cells transpire but slightly. A covering of hairs prevents too rapid transpiration, and the bloom of such fruits as plums has a similar effect. Large leaves necessarily involve much transpiration, and hence the need of a good deal of water. So we find plants with thin, small leaves usually in dry places: those with big leaves in damp ones. It is quite obvious that unless the plant is

to dry up and wither away, or undergo the process sometimes called wilting, there must be a sufficient supply of water to its tissues in the form of sap to compensate for that lost in the process of transpiration. Indeed, it is surprising what large quantities of water do pass through plants in this manner—large, that is to say, in proportion to the total size and weight of the plant itself. It has been estimated that a plant of corn will give off about 31 pounds of water in 173 days. A sunflower has been observed to transpire rather more than a pound a day of water for 140 days. A grass-plant will give off its own weight of water in hot summer weather. If this be estimated for a whole field under grass, it would give no less than about six and a half tons of water, for twenty-four hours, per acre. A birch-tree, having some 200,000 leaves, and standing in open ground, would transpire on a hot day from 700 to 900 pounds. These calculations are given by Mr. Bergen, of Boston, U.S.A. The figures give some idea of the relatively large quantities of water which must be taken in from the soil in order to supply this loss.

SECTION OF BRANCH, PETIOLE, AND LEAF, SHOWING EPIDERMIS, PARENCHYMA, AIR-SPACES, STOMATA, AND WOODY FIBRE

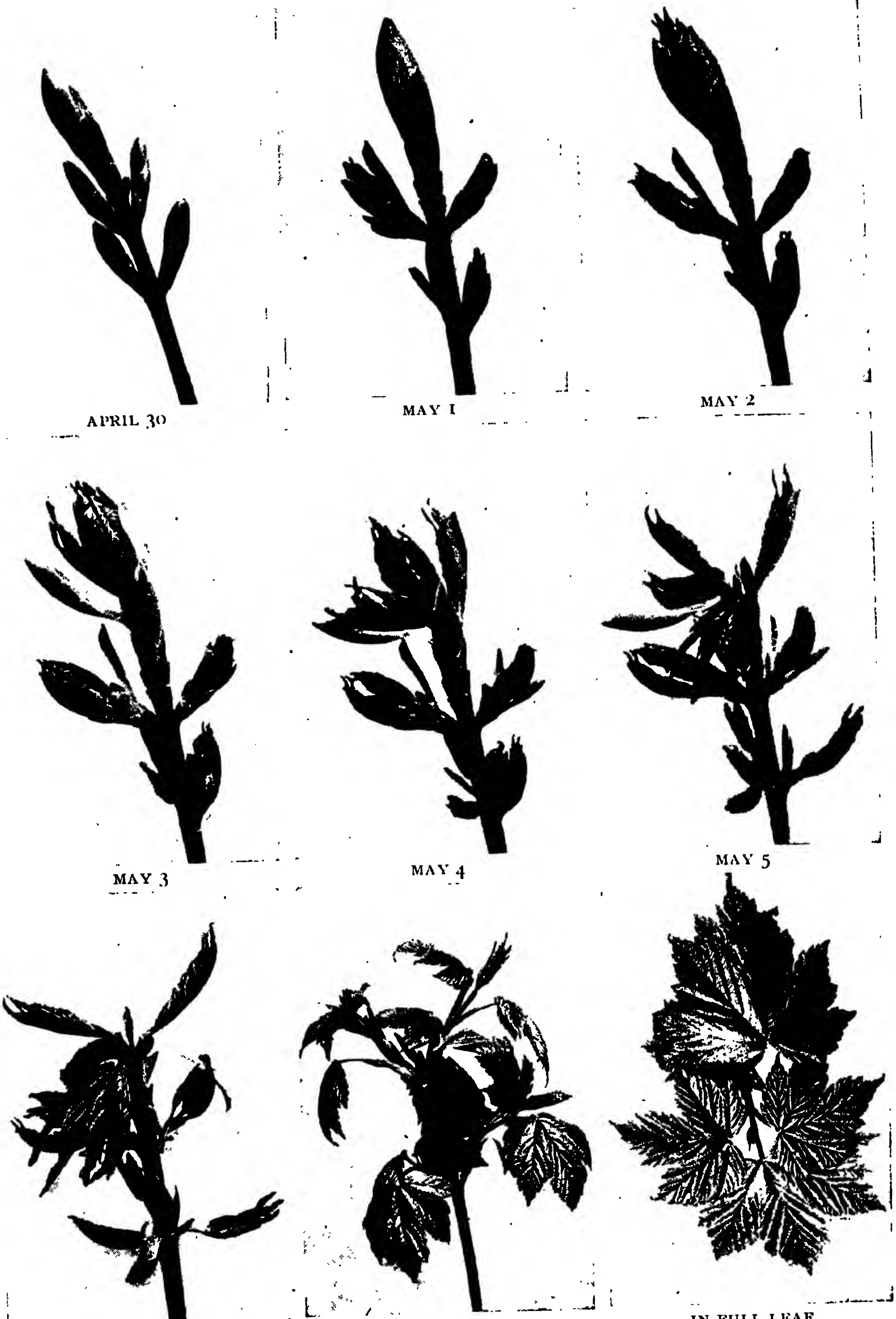
Water is, of course, also the means whereby the mineral matter in the plant reaches it; and this mineral matter is found in old leaves, and is responsible for the large quantity of ash left from a bonfire made of such material.

The next important function performed for the plant by means of its leaves is that of respiration, which must not be confused with the process of transpiration just described. Respiration is practically the same process in both plants and animals, and consists essentially in breathing in oxygen and giving out carbonic acid gas. It is a necessary process in order to obtain energy and a plant requires energy just as much as does an animal, in order that it may grow and reproduce itself. In both plants and animals the great source of energy is oxidation, especially of such substances as fats, starch, and sugar. The truth that this process of respiration is just as essential for the life and health of plants as it is for animals can be shown by simply depriving a plant artificially of fresh air. Under such circumstances it very quickly shows signs of failing health. In ordinary outdoor plants there is, of course, no difficulty about this supply of oxygen, but it is very difficult in the case of the roots which in certain soils cannot obtain as much as they require.

The oxygen required for every single cell enters the plant by means of the stomata in the leaves, and also by apertures in the bark, and it finds its way through the tissues by means of the minute spaces between the cells. The carbon dioxide gas given off is, of course, derived from the substances which make the body of the plant itself, and it is therefore a destructive process as far as plant tissue is concerned. Carbon is lost in respiration just as it is fixed in the opposite process of assimilation. The respiration process is a continuous one in all cells, going on both day and night, whereas the process of fixing carbon in the tissues of the plant is restricted to special cells—namely, those which contain the green colouring matter, and is, moreover, only performed by these in the presence of sunlight.

These two processes of respiration and carbon fixation are going on simultaneously during daylight, but much more carbon is used by the plant than is lost by respiration.

NATURE AS MAKER OF MOSAIC PATTERNS



APRIL 30 — MAY 1 — MAY 2

MAY 3 — MAY 4 — MAY 5

MAY 6 — MAY 15 — IN FULL LEAF

THE DEVELOPMENT OF THE WINTER BUD OF THE SYCAMORE INTO ITS LEAF-PATTERN

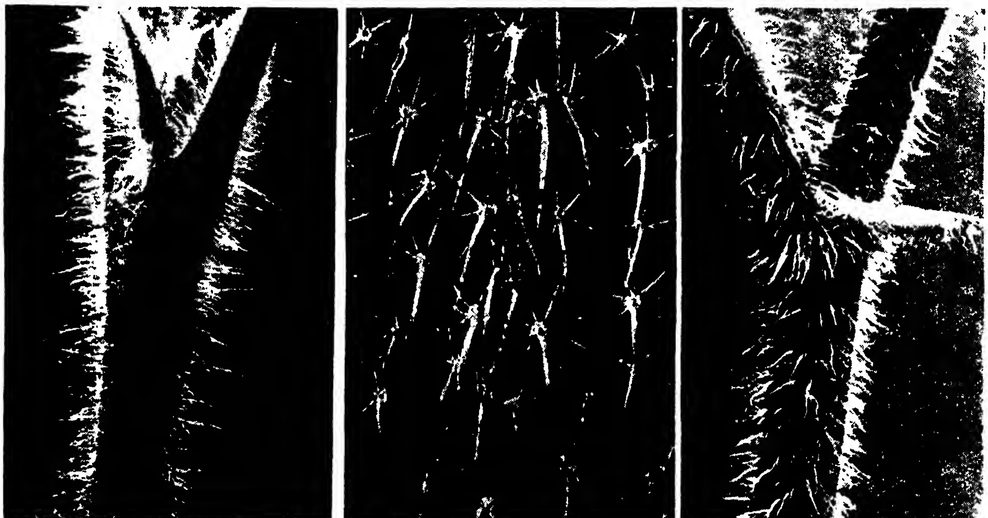
The result is that the carbon dioxide in the air is continually decreasing, whilst the oxygen is increasing. Indeed, it is only at night, when the carbon fixation ceases on account of the darkness, that the respiration becomes obvious.

The two recognisable incidents—namely, the absorption of oxygen by the plant, and the giving off of the carbon dioxide gas—are to be looked upon merely as the beginning and the end of a long chain of complicated chemical changes—changes in which the oxidation of starch and sugars and fats takes place, but which are so complicated that many of the intermediate stages are beyond recognition. This oxidation sets free the energy that enables the plant to perform its various functions, just as happens in animals also; and should anything interfere with it, the result is very soon seen in the cessation of the streaming movements of the protoplasm in the cells, as well as in the stoppage of all growth and movements associated with leaves and other organs. We see, therefore, that the absorption of carbon dioxide and the removal of its carbon is a very important function in leaves; and when we remember that this gas is normally present in the atmosphere in the proportion of four parts in every ten thousand, where it is produced by the decay of animals and vegetables, by respiration, and by combustion of all sorts, it is at once clear how important a part is played by plant respiration in Nature's scheme of things.

The next important function of the leaf which we may note is the manufacture of starch, composed of hydrogen, carbon, and oxygen. Water is, of course, largely composed of hydrogen, so that in these two sub stances, water and carbonic acid gas, we have the three elements necessary for the formation of starch.

True, it is impossible to produce starch in the chemical laboratory by putting these three elements together, but it is just precisely that performance of which the plant is normally and eminently capable.

The manufacture of starch is one of the active processes constantly going on in the green portions of the plant under suitable conditions of temperature and sunlight, provided only that water and carbonic acid gas are supplied. The active agent in the making of starch is the protoplasm of the cell, which may be regarded as the manufacturer, while the chlorophyll bodies are the actual seats of the manufacture. Indeed, the whole process has been very aptly compared by various botanical writers to that which goes on in a mill. Thus, the mill itself is represented by the palisade cells, and those underneath them; the raw material used for the manufacture is the carbon dioxide and water. The machinery in the mill is the chlorophyll; the source of the energy by which the mill is driven is the sunlight; the manufactured product turned out by the mill is the starch; and as in most manufactures there are some by-products, so in this case there is one, which is the oxygen. This simple analogy enables us to clearly grasp this important process. It follows, from what has been said, that plants which do not contain chlorophyll cannot manufacture starch.



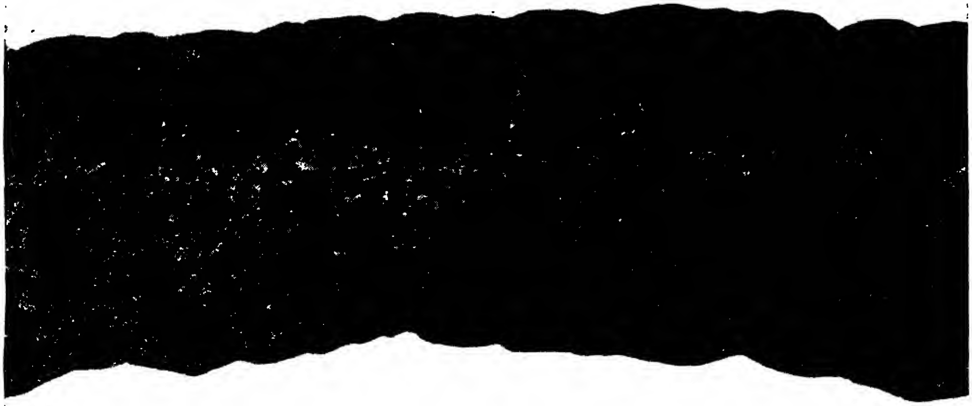
HAIRY STEM OF LUPIN — HAIRS ON A LEAF OF BORAGE — HAIRY STEM OF BEGONIA

The starch having been made, the process is continued further, and from it sugar is formed, and this in its turn combines with other elements, such as nitrogen and sulphur and phosphorus derived from the soil, so that finally we have produced very complex nitrogenous compounds, from which protoplasm itself is derived as required, and from which also the proteid foods are obtained. This further process of the changing of starch into other compounds is that of assimilation, and is also a function of the leaf. It is, however, not confined to those structures, but is, of course, going on in different parts of the plant.

We see, therefore, that, briefly stated, there are four distinct functions performed by leaves—namely, excretion of water, respiration, starch-making, and assimilation.

curious movements they make in order to attain these ends. Many leaves have daily movements—that is to say, they change their position, or the position of their parts, according to the light and the temperature. If the sun be too hot, some plants can turn the edge of the leaf towards the sun, keeping their surfaces horizontal only when the temperature is cooler. Then there are the movements taking place in the leaf during the night—the so-called "sleep of plants."

The bean and the clover plants are examples of some whose leaves occupy quite different positions at night from those seen in the daytime. In red clover the leaves droop during the night. Many plants in tropical countries fold their leaves together in the hours of darkness, and possibly these sleep-movements have some



TRANSVERSE SECTION OF THE BLADE PORTION OF A LEAFLET OF HORSE-CHESTNUT

The epidermal layer is seen above, immediately below it are the dark palisade cells containing the chlorophyll, or green colouring matter still lower are spongy cells and air-spaces, into which the stomata in the lower epidermis open.

One further point must be noted before we leave this part of our subject. Every autumn our eyes are delighted by the brilliant tints of autumnal foliage which precede the annual falling of the leaf. The colours are principally those of yellow, shades of red, and purple, variously combined, and these colours are caused by the changing and breaking up of the original green chlorophyll. Certain substances are withdrawn from the chlorophyll, and leave it yellow; and, prior to the time when the leaf actually falls, most of the protoplasm of the leaf has been transferred to the branches or the roots, where it can be utilised in the following spring.

Lastly, in connection with leaves, we must note the wonderful and interesting manner in which they adapt themselves to obtain sunlight, air, and water, and the

connection with protection from cold. The movements themselves are produced by structures at the base of the leaf-stalk, which cause the stalk to bend in one direction or another, and so alter the attitude of the leaf. Many leaves—for example, those of the iris—are so arranged as to catch the morning or evening sun fully, whereas the midday sun falls upon their edge. The leaves of many plants show movements which turn them so as to face the light as the direction of the latter changes. The object is evidently to allow the rays to fall upon the surface of the leaf. Hence we usually find leaves so arranged that their upper surface catches most of the light. In some this turning towards the light is so strongly marked as to be continuous during the day, as is the case in the sunflower, which takes its name from this fact.

NATURE RED IN TOOTH AND CLAW

A CONFLICT BETWEEN AN ADULT WALRUS AND TWO POLAR BEARS

The photographs on these pages are by Lewis Medland, W. P. Dando, J. Bell, and others.

FIN-FOOTED CARNIVORES

Intelligent and Affectionate Creatures Hunted with Ruthless Cruelty Between Land and Sea to Decorate a Lady

BLIND EXTINCTION OF ANIMAL RACES

The limbs of animals possessing backbones are derived from the fins of their fish-like ancestors. The seals are fin-footed. Are they, then, to be reckoned highly specialised fishes? It is hardly a conclusive answer that the true seal, a prince of the waters, has, when young, to be taught to swim, and cannot, therefore, be descended from a fish. Man himself, who derives from a gill-breathing water-dweller, does not swim naturally, but has forgotten the art that was anciently a fundamental necessity of existence. The genealogy of the seals must be sought in other directions than this, though the fact, taken in conjunction with others, has a decided value. It is easier to convince the sceptic of the true mammalian character of the seals than of the whales. The seals make their living in the waters, it is true, but they are simply flesh-eating, water-dwelling mammals.

Scientifically they are classed as a sub-order of the true carnivora, and, with the latter, constitute the fourth mammalian order. We can trace them as far back as the Miocene period, but no further; and, although they present certain resemblances to living animals, as to the bear, and, more particularly, to the sea-otter, the resemblance is purely superficial, and has no true significance.

The seals are directly descended, it is thought, from primitive carnivores, the creodonts, which were swept out of existence in the stress of competition with the animals of more highly organised brain from which the true carnivora developed. The ancestors of the seals and walruses went back to the waters. They left the land as four-footed animals, possessing the same number and arrangement of bones with other carnivores.

Their limbs have undergone a strange transformation, with the result that, although the five digits remain to each foot, all four of the latter have become modified into paddles, or fins, still serviceable for progress, of a shuffling sort, on land. We use the term "fin" for lack of a better, but, except in the true seals, which have the most degenerate of hind limbs, the fin-like function of the feet is more apparent than real. The limbs are enclosed up to the wrists and ankles by the skin of the body, but, whereas the true seals have the hind feet thrust straight out and backwards, the eared seals can, by arching the body, draw the hind feet under them, and employ them for land travel. The true seal, on the other hand, when it leaves the water, brings the under part of the feet together, like the hands of a man about to take a header into the water.

But, it may reasonably be asked, why, when the whole build of the seals and walruses is so remarkably adapted to an aquatic existence, should there be this retention of limbs for land travel? The reason is that the members of all three families are born land animals. Man walks before he can run; the pinnipeds walk, so to speak, before they can swim. The presumption is that when the ancestors of the fin-foots first took to the water they were as agile on terra firma as most other carnivores. But in the unending and sanguinary struggle for a living they had brain enough to discover that the path of least resistance lay in the waters, and they betook themselves to that path. They must have been animals of a high order of intelligence, for it is to be supposed that their life in the sea would not so highly tax their mental capacity as to have necessitated the really fine brain which they now possess. The brain of the seal is an excellent one, and the animals

are highly educable. Strange as it may seem, these creatures, whose way lies in the vasty deep, are, under favourable circumstances, more easily domesticated than almost any other animal, and show remarkable affection and intelligence. Perhaps it is because the captive seal is more under observation than the free animal, but it always seems as though the intelligence of these animals finds its highest expression when in association with man, and not when at liberty.

For all their wonderful brain, the pinnipeds when at large display the greatest stupidity at times, and, even when not pursued by man, fall victims in thousands to their blind persistence in seeking sandy shores as breeding places, where the young become infested with a species of roundworm (*Uncinaria*). The eggs of this parasite lie dormant throughout the winter in the sand of the breeding places of the fur seal. When the seals return from their winter migration, the eggs become attached to the fur of the adult seals, and pass from the body of the female into the interior of the infant seal, where they develop and multiply, at the cost of the young seal's life, feeding upon the blood of the animal until the latter dies of anaemia.

The Lack of Sufficient Adaptability in Seals to Escape Disease

This parasite cannot exist on rocky rookeries, but the intelligence of the seal falls short of reasoning power enough to grasp the danger to its kind from sandy nurseries, and the lives of thousands of young seals yearly pay forfeit. An animal whose feelings are sensitive enough to induce it to shed actual tears of woe when ill befalls its young, which happens in the case of the seals, might perhaps be expected by this time to have learned to avoid these death-traps. But then we might also expect seals to avoid bringing forth their young upon land at all, and so escape the hideous slaughter inflicted by man. It is quite likely, however, that the land parasite would be equal to the task of changing its habitat too, as the flea that once flew has; and continued residence in the sea would not bring immunity from man, as we shall presently see. If we could give the seals a few million years free from man-persecution, and with no enemies worse than parasites and such animal foes as the Polar bear on land, the shark and the grampus and other deep-sea terrors in the waters, they would probably make themselves masters of a wiser way in life. But that is beyond the best of us.

Our present sub-order embraces three families. The first is the eared seals, and is made up of the sea-lions and sea-bears. The next consists only of the walrus; while the third is divided into nine genera, the last being the mighty sea-elephant. The first family, then, is that of the sea-lions and sea-bears, of which there is one genus, comprising nine species. There is no difficulty in distinguishing members of this genus from the true seals. They have distinct external ears; the true seals have not. The eared seals have a well-defined neck, and their hind feet turn forward, not outward in the manner of the true seals.

The Curious Diversity of Habits in the Sea-Lions and the True Seals

The sea-lion has a coat of close hair, and is sometimes termed a hair seal; the sea-bear has a close, woolly undercoat beneath the long hair, and this is the fur seal. The long hairs are removed by the furrier, and the beautiful undergrowth remains as the fur of commerce. Sea-bears and sea-lions frequent the same shores for breeding, though not seeking the same sites; and the genus is widely represented in both the Northern and Southern hemispheres, though missing from the North Atlantic.

Sea-lions, using the term to describe the whole of the eared seals, differ in habit from the true seals, in that they pass a good deal of their time on land, and make regularly for fixed breeding places, where each male becomes, or seeks to become, the lord of a harem. The true seals, on the other hand, do not undertake these long migrations, but rear their young upon land, or, more particularly, upon ice-floes, near which they may happen to be at the right time. Moreover, the true seals are for the most part strictly monogamous. A "rookery" of sea-lions has often been described, but the picture is strange enough to warrant a brief recapitulation.

The Sanguinary Battles of the Mating Sea-Lions

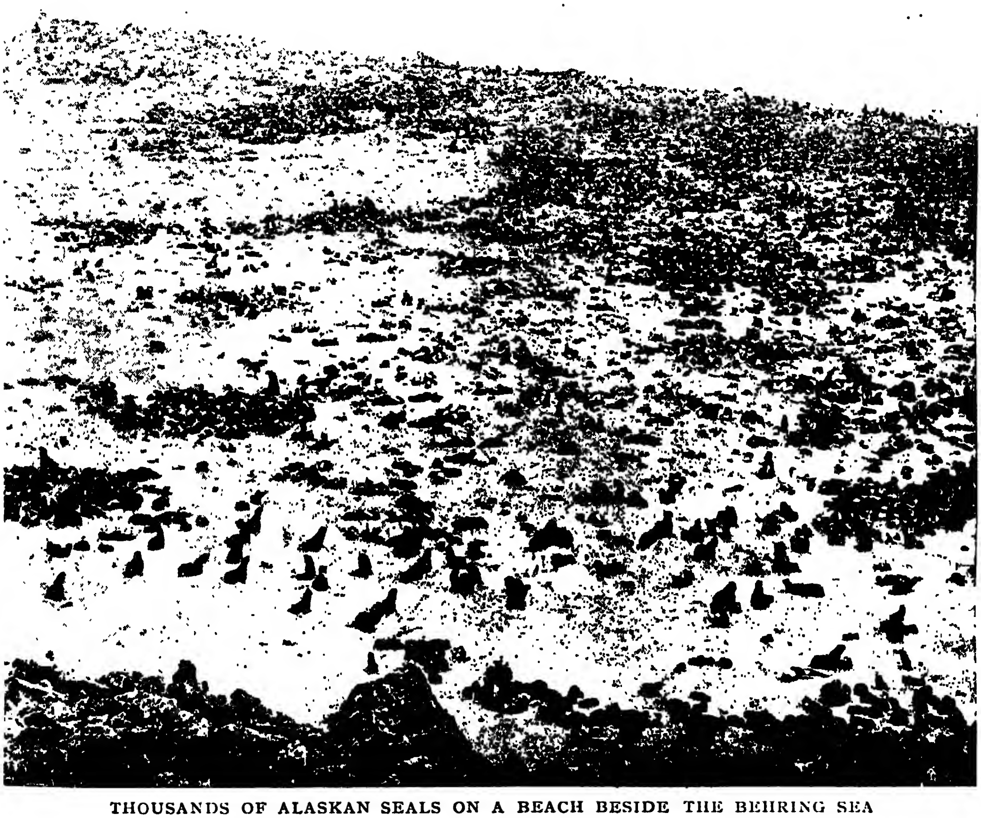
The bulls arrive first at the breeding grounds, towards the close of May or the beginning of June. The females follow about three weeks later. Each of the strongest bulls takes his own station, some ten feet square, and to this he seeks to cajole or bully the fairest of the opposite sex. But as many beating hearts may be set upon one and the same acquisition, the right to possession can be decided only by combat. Here, of all places,

" . . . The good old rule
Sufficeth them, the simple plan,
That they should take who have the power,
And they should keep who can."

Sanguinary battles accompany the choice of females. The males nearest the sea make their choice there, and haul their loves high and dry to land. But as another female appears at the water's edge, the gallant male goes to her assistance too, and in his absence a second bull steals the unguarded cow, only perhaps to lose her to another rival. And this sort of thing continuing, the female, first settled upon a water-line station, may find herself finally deposited in a seraglio fully 150 feet inland, having in the meantime been hauled from station to station by upwards of a dozen rival males. Each transference causes a battle, and the life of the sturdy old bulls down upon the coast is one long round of engagements until the last female has come ashore.

The fighting is done with the mouth. The rivals spar and feint with averted heads, then thrust out their long necks and fasten on with their powerful teeth. Once the jaws close they do not reopen; the flesh must tear. Gouged eyes, flippers torn to ribbons, and hide and blubber sorely gashed mark the price which the victor has paid for his many victories. There are always more males than harems. The unsuccessful are driven inland, and among these may be some who have set up housekeeping and then been ejected after battle.

Peace comes at last; and in the enjoyment of domestic harmony, wounds and quarrels are forgotten, unless one sultan should trespass beyond the borders of his own domain into that of a neighbour. Very soon after their arrival, the females give birth each to one young one, or, rarely, two. Then they are at liberty temporarily to revisit the sea in quest of food. They do not desert their little ones, but return to feed them, and it is a well-established fact that the mother can distinguish the cry of her own pup or calf from a host of others



THOUSANDS OF ALASKAN SEALS ON A BEACH BESIDE THE BEHRING SEA

and go unerringly to it. It is while the mother is on these feeding expeditions that such cruel havoc has been wrought by seal-hunters, who slay the animals in the water. Of course, at such times only females are on the move. The males never leave land from their first arrival, but pass, it may be, four months on shore without food or drink. Here it should be mentioned, by the way, that the sea-lions do not drink, in the ordinary sense, but are content with such moisture as adheres to the fish that they eat. True seals do drink, occasionally. To return, however, to the matron in the midst of the sea.

The quest of the pelagic sealer is not confined merely to the breeding months proper; it extends over the period during which the seals are making their way to the breeding grounds, at a time, of course, when the females are about to bring forth their young. Those that then escape have to run the gauntlet whenever they go out to feed, and as the distance covered extends to between a hundred and two hundred miles the danger is considerable. Every female killed at such a time represents the loss of three seals—the mother, her young one on shore, and a further young one which should be born in the following summer. For, very soon after the birth of one little seal, the matron has expectations of producing a successor. Therein lies the mischief and much of the horror of the trade. For every female seal killed under such circumstances there is a pup seal left to die of slow starvation on shore, and there can be no possible doubt that the official estimate is well within the mark when it states that the ocean catch of 27,000 and odd skins in a recent year represented a loss to the herd of over 75,000 animals. It is from the slaughter of these seals at sea that the genus has been driven within measurable distance of extermination.

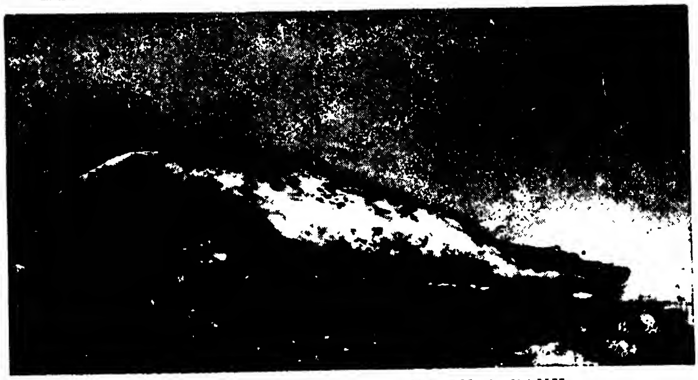
THE MONK OR MEDITERRANEAN SEAL

But it has brought a wonderful thing to pass. The nations interested in sealing have met and agreed upon a close time for fifteen years. Not a seal is to be taken in the ocean by any ship flying the flag of one of the signatory Powers until June, 1926. Those Powers are Great Britain, Russia, Japan, and the United States. It is a remarkable agreement, remarkable in more ways than one. In the first place it evinces recognition of the fact that, of all the old breeding haunts of the fur seals, only two remain in all the world of any serious commercial account, and those are the Pribylof Islands, Alaska, the property of the United States, and the Commander Islands, in the Behring Sea, the property of Russia. Other ancient strongholds have been desolated, so much so that seal nurseries owned by Japan are not deemed worthy of mention in this agreement. It is a striking and saddening thing that there should have to be this admission in an international treaty.

The second remarkable aspect of the compact is this: that four great Powers have had to confess that unless old methods are summarily inhibited, the fur seal will soon be as dead as the dodo. And to prevent this we have the extraordinary spectacle of two Powers buying off the other two Powers. Russia and America say to Great Britain and Japan: "If you will cease catching seals in the sea and leave the business to us on land, we will repay you to the extent of fifteen per cent. of our catch." To that course the other two nations have agreed, and the bargain came into effect in June of 1911. But, be it noted, this applies only to the fur seal, not to the true seal. Commercial prudence, not pity, has dictated the move.

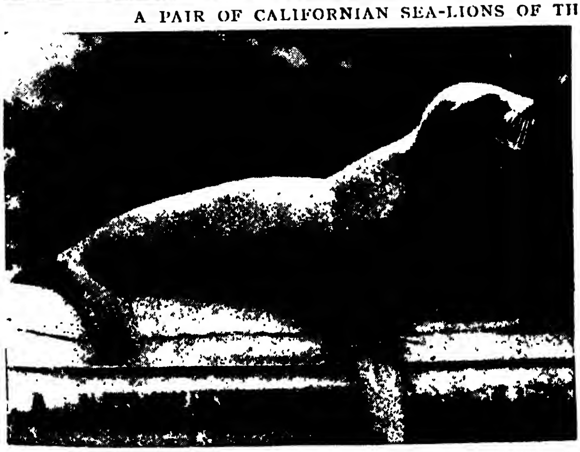
There is an enormous market for seal-skins. America has made a double profit on them, first by their sale, secondly by import duties after they have been returned from dressing in England. She paid, roughly, £1,500,000 for the whole Alaskan territory, and for twenty years received from sealskins alone more than twice the total of her purchase money for the entire territory. But in those days the seal herd numbered 2,500,000, with vast potentialities of increase. Insensate slaughter on sea and land—eighty per cent., it is computed, at sea—brought down that splendid herd, in less than thirty years, to 185,000 seals. Another year or two of unchecked slaughter would have seen

VICTIMS OF EXTERMINATING LUXURY



THE NORTH ATLANTIC GREY SEAL ON THE WATER AND ON A BANK

A PAIR OF CALIFORNIAN SEA-LIONS OF THE NORTH PACIFIC OCEAN



A SOUTH AFRICAN SEA-LION

A YOUNG SEA-LION

the end of the genus of Northern fur seals. And that is why this sensational international treaty has been effected. Now the sealing is to remain in American and Russian hands. The arrangement is that only the superfluous males will be killed, and those at the breeding places, when sex can be instantly determined before the lethal blow is struck. But the Powers ought to have gone a step beyond the dictates of commercial prudence; they should have spoken one word in pity.

There is no more sickening chapter in the pages of commerce than that relating to seal-hunting. It is a sanguinary, brutal, disgusting business, and if the details were but known and realised it would make us all for ever forswear sealskin. The hunters descend upon these lonely nurseries, head off the seals from the water, and drive them like sheep inland to the killing grounds. The wretched animals, all unfitted for land travel, are driven over miles of rocky, broken track. Panting, struggling, foaming at the mouth, falling exhausted by the way, they are urged forward, and when at last they come to the appointed place they are made to pass between men armed with bludgeons. With such force are the seals struck that, according to an official publication, "the crystalline lenses of their eyes fly out from the orbital sockets like hailstones."

A YOUNG AND TUSKLESS WALRUS

Another official account of such scenes contains the following note: "The flying of the eyes from the struck seal, the crush of the skull, the flow of blood, the sobs of the dying, and the brutality of the heartless and careless men, was awful." There is indisputable evidence that seals are not infrequently skinned while yet alive. Says Captain Borchgrevink: "If it is not dead it is generally considered 'all the better,' for it is easier to skin a seal while it is half alive. In the utmost agony the wretched beast draws its muscles away from the sharp steel, which tears away its skin, and thus assists in parting with its own coat."

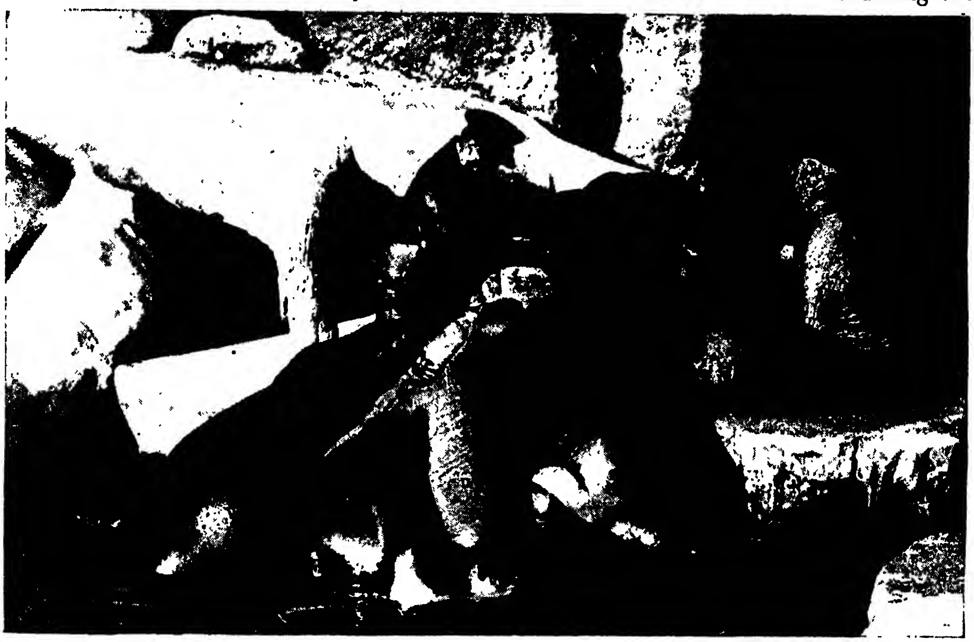
Equally shameful is the treatment of pregnant seals, which, out of coat themselves, and therefore useless, are killed in order that there may be obtained the fœtal sealskin, which is more prized for its softness and delicacy than all other forms. Surely, if facts such as these were driven home to the public mind, the sealskin would no longer be the hall-mark of affluence and prosperity. But it is these things which make us wish that the wonderful treaty did include one word of pity for the animal itself. Commerce, not humanity, speaks in the epoch-marking agreement. There is nothing new in that, of course; more than a century ago the Russian Fur Company threw into the water at Unalaschka, their then chief fur-trading station, 700,000 sealskins, not for conscience' sake, but "in order not to glut the market."

Sandwiched between the eared seals and the true seals come the walruses, huge sea animals, larger even than the largest of the sea-lions, though these latter attain a length of 13 feet and a weight of 1300 lb. It is in bulk rather than in length that the walrus exceeds the sea-lion, the weight of large specimens being estimated at as much as 3000 lb. Like the eared seals, the walrus turns its hind feet under the body to assist it when on land, but its tusks constitute the feature by which even the tyro can immediately identify it. These tusks, which are of dense ivory, are produced from the upper jaw, and measure from 18 inches up to 32 inches. The habits of the walrus are less well understood than those of the seals; butchers, not Nature students, are, as a rule, its human visitors. It is well known, however, that the tusks act mainly as weapons, and perhaps are employed in rooting among

sediment and weed for the small marine creatures which, with molluscs, form its diet. The teeth are few in number, and reduced to mere pegs, barely clearing the surface of the gum. Restricted now to the coldest waters, the walrus at one time had a considerable range, and anciently was a British resident. Today it is one of the dying groups. Its icebound home is no sanctuary. Its blubber yields abundant oil, so the animal must die.

The walrus is quite harmless unless attacked, when a male will fiercely retaliate, and overset the stoutest boat. Many cases are recorded of walruses acting in concert in these circumstances, after one of their number has been injured; and at such time they are foes much to be feared. They betray considerable solicitude for a wounded comrade, and hunters take advantage of this to slay all within reach; the animals that might escape unwounded remain to help the injured, and all fall victims to their persecutors.

Herr Hagenback, who has had fortunate experiences of young walruses in captivity, mentions an instance in which a certain sea captain, of whom he was in the habit of buying captured walruses, discovered, on the coast of North East Land, 370 of these animals, all females. "Every one of them was slaughtered by five ships' crews." It would be interesting to know whether this incident has any connection with a crime against Nature cited by Lieutenant-Colonel William Wood in an address delivered recently before the Commission of Conservation at Quebec: "Not so many years ago some whalers secured a lot of walrus hides and tusks by having a whole herd of walruses wiped out, in spite of the fact that these animals were at that very time known to be the only food available for a neighbouring tribe of Eskimos. The Eskimos were starved to death, every soul among them, as the Government explorers found out." What should we have said had robbers descended upon St. Kilda and captured the sea-birds' eggs, the only food upon which the people of that little island had to live during the long isolation from the rest of the world relieved in May, 1912?



FEEDING A HERD OF YOUNG WALRUSES IN STELLINGEN PARK, NEAR HAMBURG

Londoners had curious evidence a couple of years ago of the terrestrial origin of the walrus. A young one, brought to the Zoological Gardens, was placed in an enclosure containing deep water. Lest this should prove too much for the young animal, which had not seen a bath since it was hauled out of the Arctic Ocean, a false bottom of canvas was made to the pond, in the hope that this might prevent the walrus from getting out of its depth. But the intended safeguard proved a death-trap; the walrus got under the canvas, and could not liberate itself. London's walrus, a supposed heir of the boundless seas, was *drowned.*

The earless, or true, seals, distinguished by characteristics which we have already considered, are a very varied group, divided into nine genera, including the mighty sea-elephant. Although they lack that extraordinary faculty of the sea-lion for balancing things on the end of the nose, they are remarkably educable and mentally alert. There seems little doubt that they have a genuine liking for music. Church bells, flinging their melody out from the cliffs over the seal's sea home, always draw these animals to the shore; while the sound of melody from ship or boat proves equally attractive. There is the suggestion that curiosity, not appreciation of harmonious sound, may account for this oft-noted phenomenon, and it is disappointing to learn that of all the animals experimented upon by musicians at the London Zoo, the seals alone remained indifferent. But it must in fairness be added that just at that time the seals were awaiting the coming of their keeper with their food, and, with a mental concentration which ought, perhaps, to be applauded, they kept their minds fixed upon one theme, and ignored the musical charms of both Orpheus and his lute.

ELEPHANT-SEALS AT THE CROZET ISLANDS

The true seals are to be found—in sadly diminishing numbers, it is true—in most seas, the majority favouring the Northern hemisphere, where they produce their young, as a rule, on the ice. They ascend tidal rivers, but are mainly marine in habit, of course. But there is this remarkable fact about the distribution of the seal: that distinct species are found in the inland Caspian Sea, in the great Lake Aral, and in Lake Baikal, which, after the Caspian and Aral, is the largest body of inland water in Asia. The supposition is that the presence of seals in these waters indicates a prior connection with the sea. But seals can travel on land—a short way in a long time. It is recorded that a grey seal traversed fully thirty miles of snow-covered land in Norway, the time taken, it is believed, being about a week. Whether they would have endurance enough to find their way from some othe watercourse to the inland seas mentioned is, of course, another matter.

Many seals are destroyed on land by Polar bears, and many in the waters by killer whales. But the shark is also an enemy of this animal. Last year the Arran fisher fleet witnessed a combat between two of these animals. A British squadron was anchored near; on the waters all that is newest in the warfare of man; in the waters the old primeval struggle continuing. The shark had got a firm grip of the seal, and the latter was more concerned to escape than to battle. One of the fishermen, though normally at war with the fish-catching seal, had humanity enough to attempt the poor animal's release, and fired a shot into the shark. The latter took no notice of its injury, but bit the seal in two, and disappeared with the nether half in its jaws. Of course, the behaviour of the shark towards the seal was no worse than that of the seal towards fish. Not far from that tragic little battle a different spectacle was witnessed. A watcher observed half a dozen seals, each a short distance from its fellow, skilfully driving a shoal of salmon towards a small bay. The seals moved in a half-circle, each keeping its place as though under command. There was no escape for the fish, and they fled towards the shore, just into the place where the seals obviously desired to have them, and there every one of them was eaten. The seals worked out their plan as intelligently as dogs shepherding sheep.

Considerations of space preclude detailed mention of the various genera of true seals, but the sea-elephant, or elephant-seal, must be noted. This is indeed a prodigious beast, with a length of from 20 to 22 feet, and a girth of from 15 to 16 feet, these dimensions relating to males only, for the females are considerably smaller. The enormous coating of blubber by which the animal is enveloped is a perfect protection against cold, for it has been found that the body of a sea-elephant

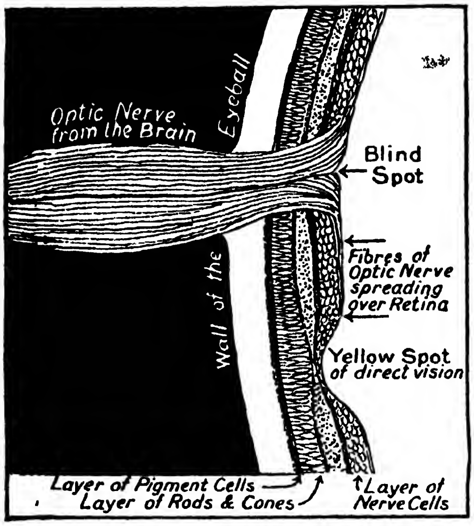
that has lain for twelve hours in the icy water of the Arctic fully retains its internal heat. Formerly to be found in enormous herds, the sea-elephant is now rapidly becoming extinct, and one species, the Californian sea-elephant, was exterminated four years ago. The end of this species aroused a good deal of controversy at the time. The last remaining few made their final bid for life on the island of Guadalupe, off the coast of Lower California. There was no law in the world to protect them; it was certain that, if left alone, within a very short time they would be slain by whalers and reduced to oil. There was not an adult specimen in any museum in the world. A wealthy English collector sent out an expedition, had them photographed on land as they lay, then had them killed and brought home to be preserved in museums. It was a race to get them. On the one hand, there was a party of Mexican concessionaires who were to slay and boil down every seal and sea-elephant on the island; on the other, there was a keen naturalist collector. The animals were doomed in any event; and today, standing before a couple of these animals admirably mounted in the South Kensington Museum, one cannot but feel that the naturalist was right.

THE FALKLAND SEA-ELEPHANT, WHICH LACKS THE WELL-DEVELOPED TRUNK OF THE CALIFORNIAN SPECIES

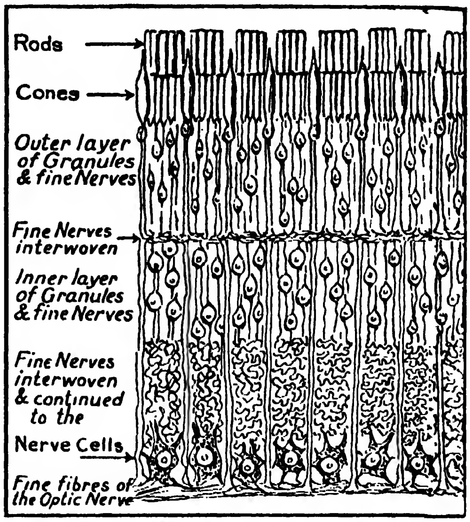
But it is hideous to think that the last of the species had thus to perish. Not all the wealth in the world could restore one of that species to the seas. All things considered, the exhibit is perhaps the most impressive in the whole of the mammalian galleries at the Museum; the size and bulk of the monsters, and the thought that they are the very last of the teeming herds that once crowded the seas, combine to fascinate the imagination as nothing else in that treasure-house of natural marvels can. It is right that we should have these specimens, but the law ought to declare that never again should it be necessary to kill the last of a species to preserve its mummy for the knowledge of mankind. Science should have its representative of every living thing, but there should be no necessity for the *last* to be taken. The nations should declare that the last shall never be reached of any species of animal in the world, if by staying the cruel and rapacious hand of man such a disgraceful contingency can be avoided. It is not suggested, of course, even by the most ardent naturalist, that the entire seal family should be granted an immunity from capture for commerce enjoyed by few other mammals. Seals work havoc on fishing-grounds, and the Danish Government pays, or until recently paid, a sum for every seal destroyed in its waters. In a case of that sort the seal is a rival to man in his industry and quest of food; and were it left to increase unchecked in all waters it would eventually constitute a serious danger to our supply of fish. The condition has not the least possibility of arising; the true seals have no friend at any Court, and seem doomed to almost certain extinction. In conclusion, it may be mentioned that the London Zoo came by accident into possession of a young sea-elephant last year, by what was thought to be a Ross's seal proving to be one of these greatly desiderated animals, but it was not one of the species mounted at the South Kensington Museum.

A BABY SEA-ELEPHANT

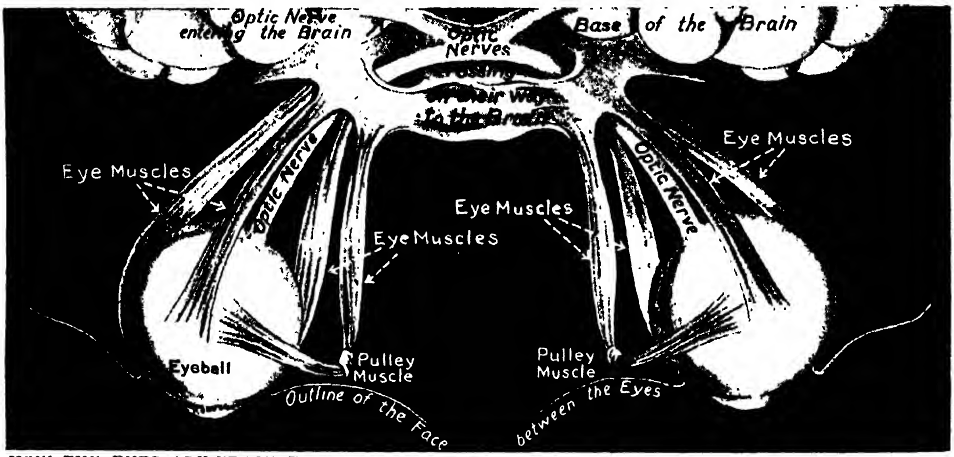
THE WONDER-WINDOW OF MAN'S BRAIN



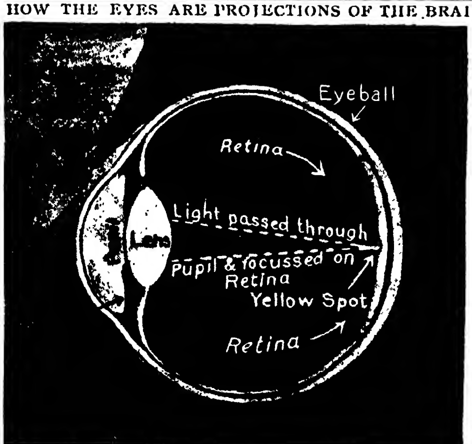
A SECTION OF THE EYEBALL THROUGH THE BLIND SPOT AND THE OPTIC NERVE



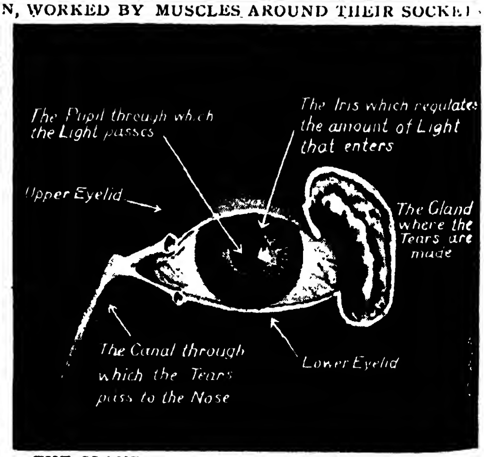
THE NERVE LAYERS AND RODS AND CONES THAT FORM THE RETINA—HIGHLY MAGNIFIED



HOW THE EYES ARE PROJECTIONS OF THE BRAIN, WORKED BY MUSCLES AROUND THEIR SOCKETS



HOW THE LIGHT IS FOCUSSED ON THE RETINA IN A PERFECT EYE



THE GLANDS AND DUCTS THAT CLEANSE THE EYEBALL OF THE LEFT EYE

THE EYE AND VISION

The Marvellous Mechanical Contrivances of the Eye for the Transmission of the Materials of Sight

HOW THE BRAIN SEES, RECALLS, & CREATES

Though not the most ancient, vision is in many ways the most important of the senses, and particularly so for the psychologist, since vision illustrates most clearly and in highest degree all the stages from simple sensation up to perception and artistic creation. The eye and the visual apparatus are themselves, of course, part of the body, but we have purposely left over their discussion, and that of the other organs of sense, in order to deal with them from the psychological point of view. We have already learnt, however, that visual sensation has its "cortical representation" on the outer and inner surfaces of the occipital or hindmost lobe of the brain. Everything that we are about to study, though of high order and largely composed of nervous elements, is to be looked upon as subsidiary to the centre of vision in the cortex cerebri. If that centre be thrown out of action, blindness is the result. No vision is possible unless the cortical centre, and the nerve fibres which run backwards straight through the substance of the brain until they reach it, are intact. We further note the difficult, mysterious, but cardinal fact that no *light* travels along these nerves or reaches the visual centre. That centre was developed and exists in absolute and unbroken darkness, though it alone sees. The waves of light which enter the eye are arrested, as we shall see, at the curtain at the back of the eye, which is called the retina. Some of the light is reflected forwards from the retina; the greater part of it is absorbed, and excites changes in the nervous elements of the retina, which in turn send nerve-currents through the optic nerve or nerve of vision, which proceeds backwards towards the visual centre. But no light travels even along the optic nerve.

The fact is that the particular kind of sensation we term vision is the peculiar property of the nerve-cells in this area of the cortex. If they exercise their function, we see. Commonly and normally they are excited by light, but that is not essential; and perhaps the best proof of the fact that no light travels along the optic nerves and back to the brain when we see is that vision may be aroused by other means than light. Whatever agent excites action on the part of the cells in the visual area will produce in us sensations of vision. These sensations may be thus aroused from without or from within. If the eyeball be struck, we are said to "see stars," and in this case the mere shock to the retina, and perhaps the sudden raising of the pressure within the eyeball, has excited currents in the optic nerve, and we have sensations of vision without the action of light. Again, in dreams, in day-dreams, in reverie, or at any moment that we will, we have sensations of vision apart from the action of light. At such times as these, remembered things

> . . . flash upon that inward eye,
> Which is the bliss of solitude.

This "inward eye," as Wordsworth called it, is of course the visual area of the cortex; and there is no doubt that when we have visual memories, or visual hallucinations, it is this area of the cortex that is thrown into action. In dreams and nightmares vision usually plays a large part; and the explanation here is that the visual area, perhaps much overworked and excited in the normal way during the day, does not wholly rest, as it should, during sleep, but indulges in eccentric activities of its own, the results of which are visual sensations on our part, though we are asleep, with closed eyes, in the darkness. This remarkable fact about the visual area is not peculiar to it, for the facts of the other centres of special sensation are the same. No sound reaches the nervous centre of hearing, but only nerve-currents

that run along the auditory nerve. That nerve may be excited by many agents other than sound, but, whatever excites it, the result is the sensation of hearing. And, further, the auditory centre may be excited in dreams, in reverie, and in the processes of memory, so that we hear, more or less clearly, either sounds which we have never heard, or sounds which are recalled by the memory, though all the time we are in silence. Thus there is an inward ear, exactly as there is an inward eye. All sensations of vision and of hearing, whether excited by actual light or sound, or by abnormal disturbance of the optic or auditory nerves, or by subtler and deeper causes, have their seat in those cerebral centres; and any activity of those cerebral centres must result in vision or hearing respectively, and in nothing else. Our clear understanding of this "law of specific sensations" we owe to the great German pioneer Johannes Müller.

But normally, of course, the visual centre is thrown into action through an astonishing apparatus, which we briefly summarise as the eye. This apparatus is definitely of double origin, in part lofty and in part humble. When we study the deeper parts of it, we find many cells which are plainly nerve-cells, but in front of these the eye consists of cells of lower type.

The Formation of the Retina from the Protrusion of the Primitive Brain

The fact is that the front parts of the eye, such as the lens, were developed from an infolding of the skin in a very early stage of development; but the back parts of the eye, especially represented by the retina, are formed in man and the higher animals not from the skin, or any of the tissues under the skin, but from the brain itself. Very early in development a protrusion appears from the front of what will be the brain. This protrusion grows forwards on what is practically an ever-lengthening stalk. As it advances, it meets the depression or infolding of the skin, which has been passing backwards to meet it. Thus the eye is formed, the retina being derived from the protrusion from the primitive brain, so that its nerve-cells are really brain-cells, as if a portion of the brain had come forwards out of the cranium in order to see; and the stalk upon which this protrusion or bulb of nervous matter was borne becomes the optic nerve.

Everything in front of the retina is therefore to be looked upon as lower in type, humbler in origin, and subordinate in function to the nerve-cells of the retina, which are, so to say, personally affected by the rays of light which the front parts of the eye merely exist in order to transmit. This transmitting apparatus first claims our attention, but we need deal with it only briefly, as its functions are wholly mechanical, and the problems of psychology lie further back. Nevertheless, this piece of machinery is remarkable enough, anticipating by some few millions of years the more modern devices which we call the microscope, the telescope, and the photographic camera.

The Bony Protection of the Eye from External Dangers

We note, then, the well-protected position of the eyeball within a bony chamber called the orbit, through the back of which the optic nerve passes outwards from the cranial cavity. The edges of the orbit are powerful and project very efficiently, so that a "black eye" commonly involves anything but the eye itself. The bony roof of the orbit is thin, however, and upon it rests part of the frontal lobe of the cerebrum. A carelessly handled umbrella may quite possibly penetrate this delicate roof of the orbit, and cause death by its action on the overlying brain. The eyebrows add further protection of a different kind, by diverting the perspiration from the forehead, so that it does not run into the eye. The eyelids are provided with hairs for a similar purpose. When the eye is open the upper lid is held up by the pull of a tiny muscle attached to the back of it. When this muscle ceases to act, the upper lid drops of its own weight, and the eye is closed. But the entire eye is surrounded with a circular muscle, one of the muscles of the face, which is also attached to the lower lid; and by the action of this muscle the eye can be actively closed and screwed up in certain states of emotion. Normally, however, the closing of the eye is simply the cessation of muscular action; and, as Tennyson knew, not many acts are gentler than the fall of "tired eyelids upon tired eyes."

The Act of Winking a Key to a Whole Branch of Psychology

More remarkable is the regular and rhythmic fashion in which, during waking, the action of this muscle is momentarily arrested and then resumed. The arrest results in a momentary fall of the lid, which is then immediately raised, and this is what we call winking. It is a reflex action, dependent upon sensations of incipient dryness derived from the front of the eyeball, but it is scarcely an ordinary reflex

action, though it is commonly so described, for the response here is, in fact, not an action, but inaction; not stimulation of a nerve, but inhibition of it. This is a very simple case, but a very significant one, for there is reason to suppose that a great many other acts, including even what can only be called acts of the will, are essentially inhibitions, as this is, and consist in forbidding what has hitherto been permitted. Indeed, it is not too much to say that the simple, familiar act of winking provides us with the key to a whole psychology of the will.

The Important Part Played in the Eye by Tears

The function of winking is clear. The front of the eye must be kept moist, with a thin, regular pellicle of fluid covering it both for clearness of vision and for the protection of the delicate surface. For this purpose there exists, under the upper eyelid, towards its outer side, a gland known as the lachrymal gland, which secretes from the blood a clear, saline fluid, practically what the physiologists call "normal saline," or "physiological salt solution," known in ordinary language as tears. The ducts of the lachrymal gland lead the tears to the under surface of the upper lid, and each time the lid is dropped it sweeps the front of the eye with a tear. How important this is for the eye is only known to the oculist who has to deal with cases where the secretion of the tears is interfered with. At the inner end of the lower lid there is a minute aperture through which the tears drain downwards into the nose. If this be blocked, or if the secretion of tears be over-abundant, they drop over the lower lid and run down the cheek. The tear-canal leads to the nose; and at highly emotional moments in a French theatre the chorus of nose-blowing confirms the beliefs even of the accustomed anatomist.

The Various Structural Parts of the Front of the Eye

The eyeball itself has a hard and dense outer coat, the "white of the eye," which is called the sclerotic. In the front of this there is inserted a circular transparent window, horny in consistence, which is hence termed the cornea. This cornea has a marked forward convexity, which is of much importance for vision. It should be neither too convex nor too little convex, and the degree of its convexity should be equal in all directions. Otherwise rays of light, say from the two limbs of a cross, will be unequally bent, and the condition called astigmatism will result. The cornea itself should be absolutely transparent and colourless. Inflammation of its surface, such as often attacks the uncared-for eyes of newborn infants, is often followed by opacity, and is the usual cause of the condition which is erroneously described as being "born blind." There are no blood-vessels in the cornea, of course, and it is nourished by lymph exuded from the walls of the capillaries which skirt it in the sclerotic.

Looking through the cornea we see a ring of colour surrounding a circular black hole which is conspicuously variable in size. The black hole *is* a hole, leading into the dark chamber of the eye; but under certain conditions, as when we throw light into the eye by the ophthalmoscope, the dark hole becomes bright, and we see clearly the brilliant red back of the eye, by means of light reflected from it to our eyes. This black hole, or pupil, is surrounded by a muscular structure, called the iris, and the interval between pupil and iris behind, and the cornea in front, is known as the anterior chamber of the eye, and is filled with a transparent watery fluid known as the aqueous humour.

The Exquisite Graduation by the Iris of Light Entering the Eye

The colour of the iris is not due to its muscular tissue, for in pink-eyed or albino animals or human beings the natural pink colour of the blood in the muscle shows itself, but it is due to the presence of pigment in certain pigment cells, upon the back of the iris in all but albinoes, and upon the back and the front of the iris in brown, hazel, and green eyes. The inheritance of the pigment upon the front of the iris—in the absence of which the eye is blue or clear grey—has lately been shown to follow the law of Mendel.

The iris is opaque, so that no light enters deeper into the eye except such as passes through the pupil. This quantity is exquisitely graduated by the iris, under the delicate nervous control of certain subordinate centres which are in connection with the retina, and so can signal to the iris according to the quantity of light which is falling upon the retina. Thus if we open the eyes before a mirror in any good light, we at once see the pupils contract, owing to the reflex stimulation of the iris by the light. When the eyes are closed this stimulation ceases, and the pupils dilate. This in itself means rest, of course, for the iris and the nerves which control it. Very few people have the wisdom, however, to appreciate the value of closing the eyes

when there is nothing to see, though this simple act rests the whole visual apparatus, from the machinery which raises the upper lids back to the vision-centre in the brain itself.

If the pupils of a friend be observed when the vision is directed from a distant object, such as a landscape seen through the window, to a near object, such as the glass of the window itself, we observe that the pupils contract in this case also, just as when more light is thrown into the eye. This is a beautiful adaptation for the purposes of clear vision.

How Concentration of Light on the Retina is Secured

The rays of light from a near object diverge so much that it would be impossible for the ocular apparatus to bring the outer rays to a focus upon the retina. Hence the iris contracts and cuts off the outer rays. This means slightly less brilliant illumination, but much clearer definition. It follows, of course, that the iris works harder when we are looking at near objects than for distant vision; and here is a clear indication for the student of the hygiene of the eye—which, however, does not concern us in this section.

The marked curvature of the cornea and the aqueous humour necessarily compel them to act as lenses upon the rays of light which traverse them. But immediately behind the iris and pupil we find a special structure, an actual lens, which has to be seen to be believed, and which may well have led Darwin to confess that he could never think of the eye without wondering whether natural selection could really account for it. This is a circular, bi-convex, transparent lens, derived from the surface of the body, like all the parts which we have hitherto studied (except the muscular tissue of the iris, which has a deeper origin), and it constitutes the front wall of the posterior chamber of the eye, which is filled with a semi-solid, glassy material—hence called the vitreous humour.

The Part Played in Sight by the Crystalline Lens

The lens itself consists of a number of fibres, each originally a cell from the outer layer of the skin of the embryo, which has been modified into a peculiar chemical compound called crystallin. This crystalline lens, to give it its full name, tends to lose its notable elasticity in middle life, and hence becomes somewhat flatter and less convex. After its shape and transparency, its elasticity is its most important and remarkable feature, for upon this alone depends the capacity of the eye to afford us clear vision both of near and distant objects. For the lens lies in a capsule which is so connected with a circular muscle, the ciliary muscle of the eye, that when this muscle contracts the pressure upon the lens diminishes and it bulges in virtue of its elasticity. But when the ciliary muscle is not in action the lens is in a condition of considerable pressure, and is therefore flattened, and made much less powerful as an optical instrument.

This means that, so long as the lens retains sufficient elasticity, its shape can be accommodated for near or distant vision. In what is called positive accommodation, for the vision of near objects, the ciliary muscle is thrown into action, the so-called suspensory ligament of the lens is relaxed, and the lens bulges in virtue of its elasticity, so that the rays of light passing through it (rays which, being from a near object, are diverging) are sharply bent and made to converge so as to form a clear image upon the retina at the back of the eye. But in what is called negative accommodation, the ciliary muscle ceases to act, the suspensory ligament of the lens is tense, the lens is flattened, and nicely adapted (in the fortunate and rare owners of such eyes) to focus the parallel rays of light from distant objects upon the retina.

The Focussing of Our Sight to Suit Different Distances

Hence, as the names imply, it is positive accommodation, for the vision of near objects, that involves strain upon the eye. It means that not only is the iris, as we have seen, thrown into more energetic action, but that the ciliary muscle is at work; hence it is use of the eyes at short distances that is liable to fatigue them.

The human eye is normally focussed upon infinity. It is ready to see distant objects without muscular effort. But, by the marvellous apparatus which the nineteenth century asked us to accept as the result of the natural selection of chance variations, the eye is able to alter its optical properties, so that near objects may, on occasion, be accurately focussed also. Modern man, however, reverses the proportions of work for which the eye has been evolved. It has been contrived so that positive accommodation, the act which involves strain, shall adapt it to what, in the past, have been occasional and usually little more than momentary purposes, before

it returns to the sky, the horizon, or the almost passive alertness for the approach of an enemy. Modern man sets this eye to work on a book for hours at a time, and then finds that it tires. We note, however, that Life has by no means finished constructing apparatus to suit its purposes. The prolonged use of the eye at short distances alters the shape of the eyeball as a whole, the constant pull of the ciliary muscle upon its attachments lengthening the eyeball from back to front, so that it becomes better suited for dealing with rays from near objects, and less strain is involved in positive accommodation. Thus we can in considerable measure permanently alter the shape of the eyeball to suit our personal purposes.

The Meaning of the Technical Terms Used in Diagnosing Sight

The technical names for the various conditions of the eye, from the optical point of view, are emmetropia (em = eu, or good, as in euphony, eugenics, etc.), where the eye is normal, hypermetropia for long-sightedness, myopia for short-sightedness, and presbyopia for the long-sightedness of advancing age, due to the diminished elasticity of the lens. These various conditions of the eye are of much importance for health, and will be dealt with elsewhere in this work. Their importance, however, is purely mechanical, and they need not further concern us here.

Hitherto we have been discussing nothing but mechanical devices for admitting rays of light, regulating their quantity, and refracting them. We now come to the retina, or curtain, at the back of the eye, on which inverted images of external objects are thrown by the action of the cornea, the lens, and the other refracting media of the eye. The retina is essentially a nervous structure. Historically, as we have seen, it is a bulb of the brain, and it is extremely rich in nerve-cells. Anatomists commonly distinguish ten layers in the retina, the greater number consisting of nerve-cells.

The Rods and Cones or Characteristic Visual Cells of the Eye

The foremost layer of cells are deeply pigmented, and immediately under them we encounter the characteristic visual cells, known from their shape as the rods and cones respectively.

These form a well-marked palisade of cells under the pigmented layer; and they are regarded as modifications of the cells which line the internal cavity of the brain. This we can readily understand if we remember the history of the retina. But these visual cells have been profoundly modified for a special function. They are not nerve-cells, as indeed their historical origin shows, but they are the cells which are immediately affected by light, and they are in intimate connection with a vast number of nerve-cells and with the terminals of the optic nerve.

Except in one area, the rods are much more numerous than the cones. Each rod has an inner and an outer segment, the latter a cylindrical pile of very thin discs deeply coloured with a pigment known as the visual purple, which is chemically sensitive to light, and especially to the blue and violet rays, just like the sensitive films used in photography. As shown on page 2382, the cones are different in shape, and their outer segment is practically colourless. At what is called the yellow spot of the retina, near its middle, the cones alone are found, and hence the marked contrast of its colour. Both rods and cones are living cells, with nuclei, but these nuclei are found at a considerably deeper level in the retina. There is a marked resemblance, on the whole, between the arrangement and distribution of the nerve-cells in the retina and the nerve-cells in the cortex cerebri—a fact which our historical knowledge of the retina as a projection of the brain itself helps us to understand.

The Blind Spot where the Optic Nerve Enters the Eye

About one-tenth of an inch towards the inner side of the eye from the yellow spot, the optic nerve enters the eye. Here the retinal elements themselves are absent, and hence this spot is blind. The presence of this optic disc or blind spot in the eye can readily be demonstrated, as in this diagram.

X

If we close one eye, say the left, and look at the cross with the right, at a certain distance the dot will be invisible, though when we move the page nearer, or further, it comes into view again. At the distance at which it disappears, the rays from it fall on the blind spot, provided that the eye be fixed on the cross, so that the rays from it fall upon the yellow spot of the eye.

Though the rods are highly specialised, and though their pigment is rapidly changed, by the action of light, first into yellow, and then into white, yet it is believed that the capacities of the rods are limited, and that they do not serve to distinguish between colours. Much higher in development, and

later in the evolutionary record leading up to man, are the cones and their concentration in the yellow spot. At this spot it is evident that everything is uniquely favourable to acute vision. Here the retina is exceedingly thin, not laden with supporting fibres, nor with blood-vessels of any size. When we look at near objects the two eyes slightly converge, so that the rays received by both eyes may fall upon the yellow spot of each retina.

What Optical Experiment Shows of the Action of the Rods and Cones

Careful optical experiment has proved that the cones, and no other level of the retina in this area, are the visual terminals; and it has been found that in visual fatigue the chromatin of the nuclei of the cones tends to disappear. It has further been shown that two objects, such as the points of a pair of compasses, which can be seen as two so long as the rays from them impinge upon the yellow spot, can only be seen as one when the rays strike upon any other part of the retina. Two objects so near together—for instance, double stars—as to affect only one cone, only afford one image. In order to get two images, two cones must be involved; and the reason why the compass-points are seen as double by the yellow spot, but not by any other part of the retina, is that in other parts of the retina the cones lie further apart, being diluted, so to say, by the rods.

Much attention has lately been devoted by psychologists to the special functions of the rods and cones respectively. They have observed that colours are not distinguished appreciably by the outermost parts of the retina, and that there the cones are very few. They have noticed, also, how the yellow spot and the cones are found only in the very highest type of eyes; and careful experiment has led to the conclusions which are thus summarised by Dr. McDougall:

The Rods the Means of Sight in a Dim Light

"The function of the rods is to enable us to see in light so dim that it cannot stimulate the cones. We may regard the rods as representing a primitive form of visual sense-organ from which the cones have become differentiated and specialised. In ordinary daylight our visual sensations are excited through the cones only, for the rods are kept in a state of exhaustion by so bright light. [We saw how light bleaches the visual purple of the rods.] But when the eyes have been shielded from bright light for some minutes, the rods regain their sensitivity. Hence on entering a dimly lit room, or on going out of doors from a brightly lit room on a moonless but starlit night, we can at first see little or nothing, for the cones are insensitive to so dim a light, and the rods are exhausted. After a few minutes, the rods having regained their sensitivity, we can see the outlines of objects, and differences of light and shade, but no colours, for the rods mediate only one quality of sensation—a slightly bluish-grey, of small range of intensity.

"If, then, one looks at a small object, such as one of the dimmer stars, it will be found to become invisible as the eye is turned directly upon it, for its image then falls upon the central region of the retina in which no rods are present. Since the rods mediate a single elementary sensation-quality, no matter what be the kind of light falling upon them, and since they are sensitive to light too dim to affect the cones, the solar spectrum, when made of very low intensity, appears no longer as a band of colours, but as a band of dim grey light a little shortened at the red end. The shortening at the red end is due to the fact that, while the rods are sensitive to rays of all other parts of the spectrum, they are insensitive to the red rays or rays of greatest wave-length."

The Cones Responsible for Sight in Bright Light and for Discrimination of Colour

"It has recently been shown, too, that the rods respond to stimulation less rapidly than the cones, so that the sensations resulting from the stimulation of them appear in consciousness an appreciable interval after those due to simultaneous stimulation of the cones."

These facts are extraordinarily interesting. The older type of organ, the rod, is *more* sensitive, we observe, in mere terms of quantity. It will respond when the cones show us nothing, so that a faint star, seen slightly askance, disappears when we look straight at it and its light falls on cones only. On the most obvious and commonly accepted criterion of sensibility, the rods are thus of a higher order than the cones. But this case teaches us what is abundantly true in the analogous case of the ear—that the true measure of sensibility is not quantitative but qualitative. The rods may be able to see where the cones cannot, but all colours are one to them, and they have nothing like the same powers of discrimination, apart altogether from colour, that the cones have. It becomes an interesting question for general, as distinguished from human, psychology to decide whether the qualities of colour sensation are appreciated

at all by those creatures in whose eyes the cones and the yellow spot are not to be found. And we are also entitled to argue, from the size of the yellow spot in ourselves, and from the quite astonishingly large area of the cortex cerebri which is associated with vision, that in man the development of this sense is pre-eminent, even though he may be neither hawk-eyed nor lynx-eyed.

When we learn that the cones are responsible for our discrimination of colours, we seem to have in our hands the key to colour-blindness, which we might expect to be due to defect of the cones. That is true of the very rare cases of complete colour-blindness, in which it is found that the retina is blind where the rods are absent, which means that the cones, though present, cannot perform their functions at all. But in other cases of colour-blindness the peculiarity is more subtle. The cones are present and perform their functions, but certain definite defects exist in the individual's colour-vision. These defects have been shown in many instances to obey the Mendelian law of transmission by heredity; and this suggests that, as in many other cases of Mendelian transmission, the factor at work is chemical. Further, cases of partial colour-blindness, such as are met with every day, usually depend upon the lack of capacity to see certain particular colours, such as red or blue.

Dr. Young's Theory of Colour-Vision in Combinations

Evidence of this kind affords a theory of colour-vision which has several variants, but is essentially one and the same in all cases. This is the theory, first suggested by Dr. Thomas Young, the founder of the wave-theory of light, that our visual apparatus contains a few units—whatever they may be—three or four in number, each of which is capable of appreciating a particular colour, and that our appreciation of all the infinite varieties of colour is due to varying blends of these few. According to Young, red, green, and blue are the primary colours, for each of which our eyes have a special apparatus; and all other qualities of colour-sensation, including white, are fusions of these three elementary qualities, or of two of them. To these three, as defined by Young about a century ago, we must now add the special greyish "colour," if so it can be called, which is peculiar to the function of the rods; and we seem therefore compelled to believe that in the visual area of the cortex cerebri there must be four distinct substances, or sets of substances, each concerned in the production of one of these four primary elements. Colour-blindness thus becomes intelligible in chemical terms, as due to the defect of one or other of these substances; and we can dimly imagine how such a chemical peculiarity, like many others, may be capable of Mendelian transmission in heredity.

Innumerable optical problems are raised in the discussion of the mechanics of vision, as, for instance, in the muscular apparatus by which the two eyeballs are moved together. These are very important for the oculist who has to deal with a squint, for instance, but they matter little to the student of man as a whole.

The Visual Memory in People who Have Become Blind

Much more to our purpose is the final question as to the seat of visual memory, and of the various processes of visual recognition, the combination of sensations to make a whole which we call perception—the process illustrated in "puzzle-pictures"—and the recall of visual perceptions and construction of new ones by the "inward eye." On this point the evidence is clear. Visual images cannot be called up by those born blind, or those who have lost their sight at as early an age as two years. But if vision has been enjoyed in the ordinary way, and then the eyes lose their functions, or are even removed by the surgeon, clear and distinct visual images may still be seen by the outwardly blind man. This is conclusive proof that the eye is not the essential factor in this process, though the past functioning of the eye is necessary. But if the visual area of the brain be destroyed or thrown out of action, no visual images will be formed. Hence we know for certain that it is the visual area of the brain which remembers, recalls, and creates. But what is the full significance of those three verbs we cannot realise until our psychological studies have gone deeper.

The Glories of the Inward Eye Lit by Memory and Thought

Meanwhile, we see that the eye is merely machinery for transmission, and that both vision and the memory of vision, leading even to the artist's and the prophet's conceptions, are achievements of the brain alone. A Homer, a Milton, a General Booth may lose the functions of what we call their eyes, and become blind. But the inward eye remains. If it has been made "a mansion for all lovely forms," it can still see beyond the darkness of the present and the grave. Such blind men are seers still.

THE SOCIAL HOUR WHICH THE BEVERAGES OF THE EAST HAVE FOUNDED IN THE WEST

AFTERNOON TEA IN THE BOIS DE BOULOGNE, PARIS

THE CUP THAT CHEERS

An Analysis of Popular Breakfast-Table Beverages and Some of Their Chief Effects

TRUTH ABOUT TEA, COFFEE, AND COCOA

Tea and coffee are not foods, but beverages which contain a special alkaloid, and thus they must be dealt with here. They are taken for their effect upon the nervous system; and though they differ in some important particulars, even so much that many people can take the one and not the other, yet they owe their essential properties to one and the same substance, which is of all drugs whatsoever the most widely and largely consumed by mankind—with one exception familiar to everyone.

The difference between tea and coffee depends upon the presence of different volatile oils, as they are called, in the two cases. These oils are not entirely without action as drugs, and they constitute the obvious attraction of tea and coffee, to which they impart their characteristic taste and flavour. But there is a certain amount of idiosyncrasy in respect of their action; and directly we venture to lay down the law, and declare that tea and coffee are practically the same, we are sure to find someone who says that tea keeps him awake, but coffee never, or *vice versâ*. In the case of many "suggestible" people, more frequently women, the particular susceptibility is purely due to what we used to call "imagination" and what is now called "suggestion." But in many people the digestion does react differently to tea and coffee respectively; and these are they who, in this respect, are fools or physicians at forty. No one can teach them what they cannot learn for themselves.

But our first business is with the essential constituent of tea and coffee, to which they owe their special properties. It is this constituent on account of which tea and coffee are chiefly taken. However, we should do well to remember that the heat of any hot liquid has potent properties even when the liquid is applied externally, as in "hot sponging," and much more potent properties when it is applied internally. There is no doubt that often the most desired and desirable effects of tea and coffee might be obtained if the specific stimulant they contain were omitted—provided, of course, that the drinker was not told of the omission. Many an invalid who is forbidden tea and coffee obtains all their effects, except the undesired and possible effect of interference with sleep, by drinking hot water. And it is quite likely that one of the reasons, if not the chief reason, why the dose of tea and coffee does not require to be increased in order to obtain their effects is that those effects are much more largely due than we usually suppose to the fact that they are commonly taken as hot fluids.

We have already made a careful study of the action of water within the body; and it is evident that the action of large quantities of heat, such as water may hold, suddenly applied to the interior of the body, close to the neighbourhood of the heart and its nerve-ganglia, must be very real and widespread. Many people have learnt to drink plain hot water, and know what a powerful application—we cannot exactly call it food or drug—this is; but many other people cannot stomach it, and that is where the pleasant aroma of tea and coffee may come to the rescue. They please and soothe the nerves of taste and smell, which are so closely connected with the behaviour of the stomach, and thus the action of the heat and the water are obtained by the kindly assistance of the flavour of tea and coffee, even when, as often happens by accident or design, these infusions are so made that the quantity of any active drug in them must be exceedingly small. This point is well worth insisting upon; for if it be really the fact

that tea and coffee largely owe their virtues and their remarkable innocuousness in most cases simply to the fact that they chiefly consist of heat and water, certainly the physiologist and the hygienist should make and keep in mind this important piece of analysis. The hot-water treatment of many conditions of the nerves and the digestion shows how important it is that we should really exercise scientific discrimination in our praise or dispraise of common habits, foods, and beverages.

The special constituent of these two beverages, tea and coffee, is a remarkable—indeed, unique—alkaloid, unique as a pure stimulant, which is sometimes called theine and sometimes caffeine, according as whether we get it from, or are talking about, tea or coffee. But it is the same substance in both; and it is rather a pity that either name disguises that fact. In the last chapter we had to discuss at length the properties of another alkaloid, called nicotine; and it may briefly be said that, in nearly all the details of their action, and certainly in all the main points, nicotine and caffeine are opposed. They form a very typical pair of what the students of drugs call antagonists. This is nought, no doubt, to the smoker as he sips his coffee; but in point of fact the drug he sips does directly tend to neutralise or antagonise the drug he is absorbing from his smoke.

The Inexact Use of the Word "Stimulant" to Indicate Antagonistic Effects

So long as alcohol is called a stimulant, and similar drugs are called stimulants, it will remain impossible for people to understand the fundamental difference which obtains between the action of alcohol and other narcotics, on the one hand, and that of tea or coffee on the other hand. Even medical men are apt to be misguided by words, like the rest of mankind. When, however, we discover that caffeine is a pure stimulant with no second stage of depression, when we learn that no experimenter has ever poisoned an animal with caffeine, we may begin to realise that the time has come for us to use such a word as "stimulant" with a little more discrimination. But it is not a little curious that, even today, though their numbers are much diminished, one or two students of drugs remain who call both alcohol and caffeine stimulants without being able to discover for us what is the poisonous dose of caffeine, and though they know and teach that, in acute alcoholic poisoning, as in acute poisoning by opium or morphine, caffeine is the pre-eminent and distinctive remedy, being the direct physiological antagonist of those two typical narcotics—because, of course, it is a typical, or rather a unique, stimulant.

Four or five years ago there was a strange movement, of dubious origin, among the few defenders of alcohol then remaining, to prove that tea and coffee are highly injurious, and that no one who touches them is in a position to state anything against alcohol. The words "théisme" and "caféisme" were invented by French writers, to indicate diseased conditions of the body that were alleged to correspond to alcoholism; and words have such a convincing way with them for many people that merely to talk of "théisme" is to persuade them that it exists.

The Lack of Evidence to Show that Tea or Coffee Produces Morbid Changes

But, plainly, it was incumbent on these writers to adduce something more than a new name if they wished to convince the scientific world; and the same may be said of a recent President of the British Medical Association, who used the one great opportunity of his life to say that tea is the enemy and alcohol harmless. These controversialists, if they wish to be credited by the scientific world, must be able to inform us as to the poisonous dose of caffeine (or theine); they should be able to show us, under the microscope or before the naked eye, at least *one* morbid change of the tissues, however small and unimportant, that can be traced to the long-continued action of caffeine. Let them point to a single tissue change, a single characteristic symptom, a single crime or death. They cannot, and do not even try to; but a section of the public is glad to hear them when they say that in their opinion or in their experience tea is far more pernicious than alcohol, though they adduce no evidence on the subject.

A Flagrant Example of Denunciation Without Scientific Evidence

A recent volume, translated from the German, is a flagrant example of the kind of thing which all sober students of diet and physiology must deplore. The author's name is not known to German science of the day, but the volume is entitled: "Alcohol, the Sanction for its Use, Scientifically Established and Popularly Expounded by a Physiologist." We shall later see that the volume on this subject which never mentions the work of Metchnikoff, nor that of Kraepelin, and which in one place

describes alcohol as a stimulant and in another as a narcotic, needs no serious attention. But no doubt its title has brought it many readers, who will find tea and coffee roundly abused and condemned in its pages. No evidence is adduced, but the author declares that tea and coffee can safely be consumed only if sufficient alcohol be taken to neutralise their bad effects; and his great maxim and rule of life in this connection is "Always more alcohol than caffeine." Only this outrageous abuse of the opportunities and privileges of science can justify us in spending a moment upon a work which has doubtless served its purpose of misleading many uninformed and uncritical readers, but which could not deceive a first-year medical student for five minutes.

An Analysis of Tea, Showing its Ingredients, Good and Bad

Let us now look more closely at tea, in the first place, and at the conditions which determine its exact effect upon us. For practical purposes tea consists of two things, apart from the valuable water and heat which we have already discussed. These two things are tannin, or tannic acid, and the alkaloid theine or caffeine. Tannin, or tannic acid, is a substance found in certain parts, especially the leaves, of a great many plants, but it does not occur in the coffee-bean; so that here we have a real and sometimes a very important difference between tea and coffee. We say "sometimes," because what matters to the consumer is not the composition of leaf or bean, but the composition of his beverage; and there may be, and should be, all the difference. The tannin in the tea-leaf is much less readily soluble than the caffeine, and is much less readily obtained from the Chinese leaf than from the Indian, which latter, like the leaf from Ceylon, contains a much larger proportion of tannin than does the Chinese leaf. Tannic acid has no attractions for the normal palate, though many people undoubtedly learn to like a little astringent-bitter flavour in their tea; but this is an acquired taste, and, like most, if not all, "acquired tastes" in the realm of physiology, is not worth acquiring.

The Bad Effects of Tannic Acid on the Digestive Tract

Tannic acid has no action whatever upon the nervous system—none of it, indeed, being absorbed by the body. It is incapable of passing through the wall of the stomach or bowel into the blood, and therefore its action is wholly a local-contact one. This action upon the tissues with which tannin or tannic acid comes into actual contact is wholly deleterious—according, of course, to its degree of strength. It would be an exaggeration to suggest that this action is necessarily serious, or even measurable in many cases, but what action there is is wholly bad. We know the feeling which an astringent substance produces in the mouth. It seems to draw the mouth-lining together, which is exactly what the word "astringent" means. But this binding and drying action on the tissues of the mouth is repeated wherever the tannin goes, and notably so in the stomach. There it is liable to interfere very markedly with digestion, and that in two ways, for it tans, as we may say, not only the stomach wall, but also any food-materials on which its action can be exerted. It is liable to form a definite chemical compound with albumin, which is thus made tough and leathery, and therefore very difficult of digestion, as many have proved to their extreme discomfort after a "meat tea." And any tannin which may remain uncombined with albumin in the stomach is bound to act in the same astringent or binding way upon the lining of the bowel as upon that of the mouth and stomach.

The Way to Avoid the Extraction of Tannin when Preparing Tea

Clearly, then, the habitual consumption of any appreciable quantities of tannic acid must interfere more or less with the functions of the digestive tract from the mouth onwards. In the mouth the secretion of the saliva and mucus which are desirable for the initiation of digestion is interfered with, and the stomach and bowel are in various ways incommoded in their turn. Plainly, therefore, a chief concern in the production of the best beverage from tea should be the reduction of the tannic acid to a minimum. This is to be accomplished, first, by using the leaf which contains least of it; and second, by sharply limiting the length of the infusion. It has been clearly proved that practically all the caffeine that can be obtained from the leaf is obtained in the first three minutes; whereas the amount of tannin increases markedly, even so late as between the twentieth and fortieth minutes—long after the whole of the alkaloid has been extracted.

We have seen the action of tannin upon the body, and now we must look at the action of caffeine, for comparative and critical study has shown that the injurious effects often justly attributed to tea-drinking are due to the tannin contained in improperly made tea, such as no one should

drink, and not to the caffeine, which should be the sole chemical ingredient of any importance, or present in any quantity, in a properly made cup of tea. Caffeine is less abundant in the tea-leaf than in the coffee-bean, but it is present in sufficient quantity to contribute very important additions of its own to the action of the heat and the water. There is no doubt that this alkaloid must be reckoned with on its own merits, for cold tea has definite properties, and so has caffeine, given in the form of a powder—in which case the value both of the heat and the water of tea (or coffee), drunk in the ordinary way, can be excluded.

Tea and Coffee Nerve-Stimulants of the Purest Kind

The almost unparalleled and persistent favour in which mankind at large regards tea and coffee corresponds to the very remarkable properties of caffeine, which is a nerve-stimulant of the purest kind, directly opposite in action to all the narcotics, such as alcohol and opium, of which it is the best antidote, and very notably different from such a powerful nerve-stimulant as strychnine. This latter alkaloid has an astonishing action upon the centres for motion in the lower levels of the nervous system, and especially upon the motor areas in the spinal cord, and those which are concerned with respiration. By its action upon the breathing, strychnine may thus favour the functions of the brain when the breathing has been feeble and the brain has consequently been ill supplied with oxygen. But strychnine has no direct action at all upon the brain, whereas caffeine is a direct stimulant of the highest areas of the brain, but does not affect the spinal cord in any degree comparable with the action of strychnine. It is this stimulation of the functions of the cerebrum, the highest portion of the brain, together with the absence of any subsequent reaction that can be detected, which places caffeine in a unique position among drugs. We know nothing like it.

The Unique Effects of Caffeine in Preserving Wakefulness

Naturally, we should expect that a drug which has this exceptional action upon the cerebrum should have exceptional relations to sleep and waking, and that is so. The doctor has no hesitation in giving strychnine near bedtime, for he knows that this drug has no stimulant action upon the brain. But the case is very different with caffeine. When the doctor is faced, for instance, with laudanum poisoning, and sees how the morphine in the laudanum is inducing a deadly drowsiness in his patient, he has instant recourse to strong coffee—or rather, nowadays, to large doses of caffeine itself—in order to combat the action of the morphine upon the highest part of the brain; and the same action is sought for the similar symptoms of acute alcoholic intoxication, where the patient is on the verge of being, literally, dead drunk, though such cases are not common, and are seldom met, except where a man has been seeing how much he could drink for a bet.

But there are other occasions on which, apart from acute poisoning with alcohol or morphine, it is necessary or desirable to keep awake. In war, on board ship, in sick nursing, and in many other emergencies which may happen to any of us, it may be essential, at any cost in reason, or at all costs, that we should keep awake; and in all such cases caffeine occupies a unique position among drugs. The writer may confess that, when a medical student preparing for an examination which included pharmacology and therapeutics, he was so impressed by what he learnt about caffeine that, in order to keep awake when books could scarcely be held any longer in the hand, he took fifteen-grain doses of citrate of caffeine every night for several weeks, without any deleterious results, and with the most marked and unmistakable action upon the tendency to sleep.

The Absence of Reaction After the Use of Caffeine

Certainly this is not an example to imitate, but it is, nevertheless, a definite physiological observation, which is worthy of record as showing what caffeine is capable of. A notable fact was the absence of reaction, just in accordance with the statements of the textbooks on this subject. After the artificial prevention of sleep, to the extent of several hours, night after night, great lassitude and incapacity to attend or to learn might have been expected during the day, but nothing of the kind was experienced, though on several occasions the drug was so used that the "patient" did not go to bed at all. There can be no doubt that caffeine has some action upon fatigue products, aiding their excretion, or breaking them up in the body, for only thus can its effects be explained. Chemically this alkaloid is closely allied to certain natural constituents of the body.

Now, it is plain that, so far as the remote consequences of a cup of tea are considered,

it is the caffeine that we desire, and the tannin that we do not desire. The relative solubility of the two substances exactly suits our convenience, if we will avail ourselves of it. If it were necessary to extract all the tannin in order to get any caffeine, there might be some excuse for the lady who likes her tea to have a little "body" in it, or for the servant-girl who keeps her teapot on the hob all day. But the fact is that it is possible to obtain all the caffeine desired, while reducing the amount of tannin to a minimum. At present the public taste is thoroughly vitiated; but no one who has given the matter fair consideration, or who claims to possess any delicacy of palate at all, will question that the fine aroma of a cup of properly made tea, more especially made from the Chinese leaf, is in a different category altogether from the sensations aroused by the concentrated solution of tannin which is usually offered under the pseudonym "a cup of tea."

For choice, then, the tea should be made from the China leaf, but this is of less importance than the actual method of infusion. It is not the composition of the leaf, but the composition of what is drunk, that matters. The briefest possible infusion is sufficient to extract all the valuable caffeine from the leaf, whereas there is a distinct difference in the amount of tannin contained after three minutes' infusion, as compared with five. The dose of caffeine in an ordinary cup of tea is about one grain.

The Manner in which Tea should be Prepared to Secure its Good Effects

The tea drunk should be an infusion, in the proper sense of the word, and the leaves should be neither stewed nor boiled, as so often happens. The character of the water is very important for a really delicious brew. The Chinese say that the best water for making tea with is that from a running stream, and the worst is well-water. This means that the water should be well aerated, like that from a running stream. If the water is boiled for a long time, all the dissolved gases are driven off, and the water is made flat, like the well-water which the Chinese condemn. Therefore, the water used should be just freshly come to the boil. If the water used be flat to begin with, it should first be poured backwards and forwards into a jug from a height in a thin stream, for so it picks up some of the air on its way. The water should not be too hard; and if only hard water is obtainable, a pinch of baking-soda may be added to the teapot. Tea-tasters employ a smaller proportion of tea than is indicated by the ordinary domestic rule. Of course, the teapot should be thoroughly heated as a preliminary to making the infusion, for otherwise the water poured into it is lowered below boiling-point, and "it is only at boiling-point that some of the volatile constituents of the leaf, to which the beverage owes its aroma, can be properly extracted."

The infusion should not last longer than four minutes. After this, too much tannic acid is extracted, as well as bitter substances which we are better without. Also, if the infusion be prolonged, it drives away the delicious volatile oil to which much of the fragrance of properly made tea is due. After infusion, the fluid should be poured into another hot teapot. The use of milk is, perhaps, desirable, as it disposes of some of the tannic acid of the tea. No second brew should ever be made, for a single infusion is enough to remove from the leaves everything that is worth having.

The Only People to whom Tea Should be Forbidden

Tea thus made is delicious; by means of its water, its heat, and its caffeine—pure stimulants all three—it is refreshing; it cannot injure the digestion, though possibly in some cases the addition of sugar to it may do so; and it may be questioned whether there is any necessity to forbid its use by anyone but the victim of insomnia, caffeine being the only known drug which, by its direct action on the brain, promotes the activity of which sleep is the negation.

In Great Britain we consume about four million gallons of tea every day, and in Australia the amount consumed per head is half as high again as in Great Britain. With this almost incredible consumption it is impossible for the opponents of tea, who oppose it merely in order to befriend alcohol, to point to any bad effects whatever other than those dependent upon the fact that tannin interferes with digestion, and is largely contained in improperly made tea. The most exact and impartial modern inquiry justifies the familiar eulogy of tea as "the cup that cheers but not inebriates."

A Comparison between the Effects of Tea and Coffee

We can be briefer in dealing with coffee, for we have already discussed the physiological properties of caffeine. The particularly seductive ingredient in coffee is its characteristic, powerful, and volatile oil, which is even more pleasant, perhaps, to the nose than to the palate. This caffeol,

as it is called, is in some degree a stimulant, like volatile oils in general, such as peppermint, for instance. But it is this caffeol which upsets the digestion in a good many people, so that they cannot drink coffee. The action upon the digestion is quite different from that produced by the tannin of improperly made tea, and there is no tannin in coffee, however badly it is made. But the powerful oil affects the nerves of the stomach in some people, so that they suffer from a nervous form of dyspepsia, and coffee must be avoided by such people.

The proportion of caffeine in coffee is not so much greater as one might expect than what occurs in tea. It is reckoned that "a breakfastcupful of *café au lait* is composed of about one part of black coffee to three of milk, and will not therefore contain more of the alkaloid than a cupful of tea." But evidently, if one drinks coffee black and abundantly, the number of grains of caffeine will soon begin to mount up, at the rate of three to a breakfastcupful. An inquiry is now in progress as to the effects of caffeine in these substantial doses, when continued over really prolonged periods; and it is necessary to withhold any too positive statements as to the entire innocuousness of coffee until those researches have been completed.

The Process by which Good Coffee may be Prepared

In order to make good coffee, one must use enough; it should be freshly roasted; it should be ground at home, the same day as it is drunk; the same conditions as to the water and its boiling should be observed as in the case of tea; and the infusion should be made in an earthenware vessel. Complicated apparatus is to be criticised, as unnecessary, and as liable to contain vestiges of stale coffee, which are quite sufficient to ruin the new brew.

No methods of filtration are necessary if the coffee be stirred and allowed to stand a little.

It has already been stated that we must be cautious, if we are to be scientific, in our judgment of coffee. Probably there are many people who drink too much coffee. *Café au lait*, in anything like reason, is no more to be feared than tea, perhaps; but the proportion of caffeine in black coffee is considerable, and the caffeol is not to be ignored, for there is reason to suppose that successive doses of volatile oils, long continued, may do harm to the kidneys, upon which fall the burden of excreting them. But here, as almost everywhere in the realm of hygiene, we must judge not by rule of thumb, but by individual experience and observation. It is a safe and useful rule, in the writer's judgment, that at the slightest hint of impairment of digestion, or of the power to sleep deeply, certainly, and promptly on going to bed, one should cut down the consumption of coffee to whatever extent may be necessary. We are here dealing, we must remember, with substances which are essentially drugs and superfluities, however pleasant they may be, and however innocent in certain circumstances. They are not necessary to health; they are in no proper sense of the word foods, any more than alcohol is, and they must therefore be judged stringently with a ready eye to any objections.

The Time of the Day when the Drug-Stimulants Tea and Coffee may be Used

Those objections refer to the action upon the digestion of the tannin of improperly made tea, and the caffeol of coffee, and to the action upon the cerebrum, when it should sleep, of the alkaloid which is common to tea and coffee. These beverages are best consumed early in the day, as at breakfast; and they must immediately be suspected whenever the problem of insomnia arises, in however slight degree. The patient may do well to drop them both entirely until perfect sleep is restored, or to take them only sparingly during the first half of the day, and not at all during the second. And it is sheer madness and folly to continue the consumption of caffeine in either of these beverages while one is at the same time taking hypnotic drugs for the gaining of sleep. This is obviously a gross abuse of the nervous system, and hosts of people are nowadays guilty of it.

The Qualities of Cocoa Under Scientific Examination

Cocoa must also be dealt with here, because it contains another alkaloid, called theobromine, which is a close ally, chemically, of caffeine. But in point of fact theobromine is a drug of such mild potency, apparently doing no more than act as a very gentle stimulant of the kidneys, that we may fairly dismiss it as harmless. It may be freely taken, for instance, by those who suffer from insomnia, and to whom tea and coffee must be forbidden.

The practical verdict upon cocoa is that it is a slightly stimulant and harmless beverage, little more and little less, even though it contains an alkaloid and certain food-materials. The proportion of the alkaloid in cocoa is very similar to that of

caffeine in coffee; but while this theobromine may be ignored, the fat of cocoa cannot be ignored, for it is very liable to upset the digestion of many people. The cocoa is much more tolerable if the fat be removed or its proportion reduced, but, on the other hand, the cocoa is then the poorer as a food. However, it is only when we add milk and sugar to cocoa that it comes to have any very substantial food-value. Without them, cocoa is not to be seriously considered as a food, though it is certainly a pleasant adjunct to the diet, and though some of its ingredients may contribute to nutrition in ways which we do not yet understand. But when we measure the proportion of food-material actually present in cocoa, we find that it would require about seventy-five breakfast-cupfuls of cocoa to yield the total amount of potential energy demanded of the body daily. Theobroma, which is the botanical name of the cocoa plant, means the "food of the gods," but if the gods really lived on cocoa they must have died of starvation long ago.

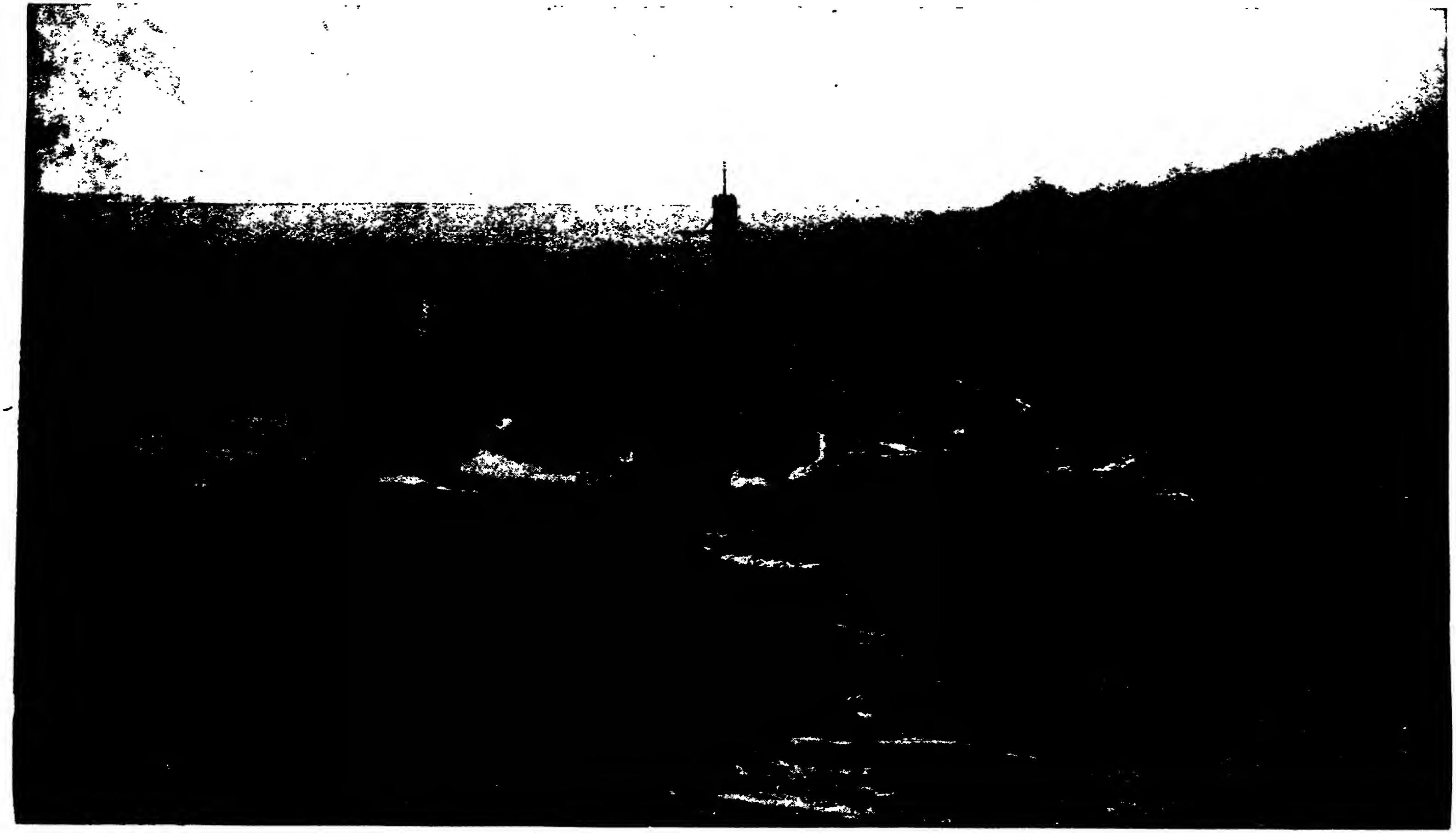
Here, however, is a beverage which has some food-value, is pleasant to the palate of many people, is an excellent vehicle for sugar and milk, and also contains an alkaloid which has a slight action of a useful kind, and no deleterious action at all, so far as we know, either in health or disease. No wonder that the civilised world has taken cocoa to its heart, or its stomach, and that its place is scarcely challenged by any substitute, even though the claims made for it as a food are unreasonable. Of course, it must be understood that we are here discussing cocoa itself. When cocoa is prepared with milk, or so as to be eaten in the solid form of chocolate, and, still more, of milk-chocolate, the case is entirely different; and with the first mouthful its food-value begins to tell. That, however, is not our present concern.

PICKING COCOA-BEANS IN ECUADOR

Cocoa in all its forms, including liquid and solid chocolate, may be generously permitted to children. It can do them no harm, provided that it is not taken beyond their digestive capacity; it is a splendid vehicle for the milk and sugar which we shall find to be so invaluable for children, and in its concentrated forms it is of substantial food-value in itself.

On the other hand, children should not be permitted to take tea or coffee. The merest flavouring of tea in milk is the utmost that should be permitted to a child, and that not until it is in its teens. Cocoa is so excellently manufactured nowadays that the child need not lack a pleasantly flavoured beverage in any case. But the caffeine of tea and coffee is a drug; and though we may employ it in reason for ourselves, and usually with entire impunity so far as we know at present, it is a drug of a kind for which the naturally active and sensitive nervous system of a child has no need. And, further, sleep is more likely to be interfered with in the child than in the adult by the use of this drug. And now we must pass to a drug of a different type, which is a common ingredient of the beverages of civilised and savage man alike, and on which the science of the last two decades has thrown a flood of light, revealing what few suspected, many resent, and nearly all ignore.

POWER AND SPEED—REMARKABLE PHOTOGRAPH OF A BATTLESHIP FIRING AT FULL SPEED



THE UNITED STATES BATTLESHIP "DELAWARE" FIRING A BROADSIDE AS SHE STEAMS FULL SPEED AHEAD

THE MIGHTIEST FORCE

How the New High Explosives are Changing the Face of the Earth

THE WEAPON OF DEATH A SOURCE OF LIFE

OF all the forces over which mankind has obtained control, there is none so mighty and so useful as fire. In an ordinary grate of burning coal there is enough explosive energy to throw a 1000-pound shell through a foot of solid steel. There is practically no difference in the chemical action of rusting iron and the explosion of cordite in the new 14-inch naval gun. A decaying tree and a burning candle are the result of a similar action. It is oxydisation. A certain amount of oxygen of the air combines with iron, and produces rust; it is an affair of weeks. In a burning grate the union of coal and oxygen is quicker—a matter of minutes. In the case of gunpowder or the high explosives used in modern industry and modern warfare, the speed with which oxygen enters into a chemical reaction is practically instantaneous. For instance, in dynamite, the wave of explosion travels at a pace of more than 5000 yards a second. A foot-length of dynamite explodes in one-twenty-four-thousandth of a second. A mile of dynamite cartridges blows up from end to end in one-fourth of a second; and a much greater speed of reaction occurs in cotton dipped in nitric acid and mixed with glycerine that has also been nitrated.

So all that is necessary in order to convert any ordinary burnable substance into a terrific explosive is to increase the supply of oxygen. Wood burns slowly, because it draws its oxygen from the surrounding air by a gradual process. If, however, the charred wood is mixed with saltpetre, which contains three thousand times as much oxygen as ordinary air does, the application of heat results in a rapid combination of the chemical elements. Each particle of the charcoal has its particle of oxygen ready to hand in the saltpetre, and the two combine with explosive rapidity, and all the solid matter swiftly expands into a huge mass of gases. It is this sudden transformation of a small amount of solid substance into a vast quantity of gas that produces an explosion. The process of oxydisation that occurs in a decaying tree or a lighted candle is simply quickened by an artificial supply of oxygen. The gases form more rapidly; and if anything stands in their path they blow it away under the enormous pressure with which they have been generated.

Such is the simple explanation of the production of the grand force in modern civilisation. A petroleum lamp burns steadily and slowly, by reason of the small supply of air that it obtains. If the air is mixed quickly with the oil, an explosion occurs that can be so regulated as to drive a flying-machine through the skies at the rate of a hundred miles an hour. The motor-car, and the new railway engine that is coming into use since the coal strike, are merely machines for transmitting the regulated power of explosion to wheels. The modern gas engine also derives its power from explosions of gas and air. In all these cases, the oxygen of the atmosphere is intimately combined with oil or gas before the chemical reaction provoked by heat is set up. So, instead of a slow combustion, there takes place a rapid process producing a sudden and violent expansion of gases. The gases strike against the piston of a cylinder and shoot it forward. In this way the motion necessary to drive the wheels of a motor-car or the propellor of a flying-machine is obtained. In other words, a great deal of the machinery in mills and factories and workshops where a gas-plant is used is harnessed to the terrible chemical forces that we hear of in their most sensational forms in connection with war.

It is not extravagant to say that modern explosives have made the modern world what it is. By mixing oxygen-carriers with various burnable substances, man has subdued the earth to his purposes. In judging of the degree of the civilisation of the people, we are guided to a considerable extent by the kind of roads and waterways they have constructed, and by the facility with which they have obtained metals and minerals and applied them to the arts. The Romans constructed excellent roads on the level, but in mountainous districts they could only make narrow and very steep paths. When Hannibal was compelled to make a road for his army across the Alps into Italy, he could only use the methods invented by the ancient Egyptians. Small rocks were cleared away by hand tools and wedges. In the case of very large stones, the fire-setting system was adopted. The rock was heated by lighting a fire on it; and when it had grown very hot it was suddenly chilled with water, and the rapid contraction often caused the rock to split.

ALFRED BERNHARD NOBEL, SWEDISH CHEMIST

It was very slow work; and when the road-makers found themselves face to face with a mass of granite too large to be broken by hand tools and fire and water, they had to twist their path round it. In other arts of peace, man's power over the earth was similarly limited. Works of irrigation could only be undertaken in a soft soil, and even then the labour was tremendous. To make a cutting about three miles long to drain Lake Fucinus, the Emperor Claudius employed thirty thousand men for eleven years. Mining was carried on in the same slow and laborious fashion, with the result that the most highly civilised races of the ancient world had scarcely any advantages in material resources over the northern barbaric tribes of Asia and Europe. That was one reason why the Græco-Roman culture was at last destroyed by a mob of savages.

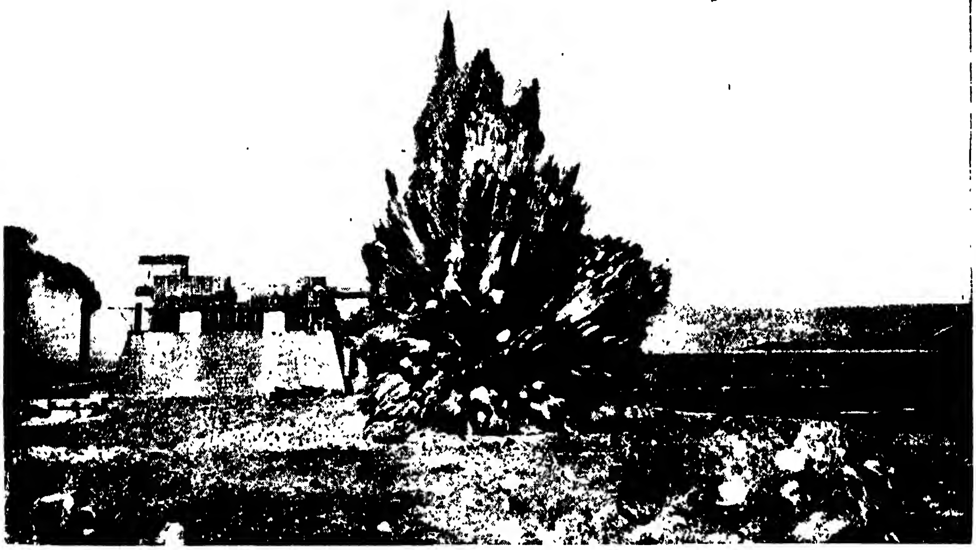
Though gunpowder was invented by the Arabs in the thirteenth century, and introduced into Christendom by Roger Bacon about 1270, fifty-eight years before Berthold Schwartz, of Freiberg, described it, the industrial use of explosive power was neglected for centuries. The science of road-making and mining was scarcely more advanced in the age of Shakespeare than it had been in the age of Virgil. Gunpowder seems first to have been employed in mining in 1613, when Martin Weigel, a mine manager at Freiberg, began the excavation of ore by means of drilling and blasting.

In 1670 blasting was introduced into England by some German miners, and it was half a century later that the Swedes learned the new process from some German miners, imported, as in England, to work the mines. Yet the German method appears to have been very slow, for it is said to have taken one hundred and fifty years to blast five miles of gallery in the Hartz Mountains. And the total space mined in Great Britain in the middle of the eighteenth century amounted to little more than that of a large railway cutting at the present day. It was the introduction of railways, and the need of laying the lines on easy gradings, that raised blasting to a science. The new steam machinery that was revolutionising our industries could then be fed with cheaper and more abundant coal, extracted from the earth by the wedge-like force of gunpowder.

Till about forty-six years ago gunpowder remained the greatest force that man could safely use. In the arts of peace and war alike, a mixture of charcoal and saltpetre, to which was added a certain amount of sulphur to absorb the water generated by the explosion, produced the expansive gases with which man killed and dug and tunnelled. As a matter of fact, a series of more powerful explosives had been discovered by modern chemists. In 1832, Braconnot transformed starch into a source of terrific power by treating it with nitric acid; six years afterwards, Pelouse and Dumas changed cotton and paper into gun-cotton

CHEMICALS DISCOVERING CHEMICALS

BORING TEST-HOLES ON THE NITRATE FIELDS OF CHILI



BREAKING UP THE SOIL BY BLASTING A CHARGE PLACED IN A TEST-HOLE

THE NITRATE-PRODUCING MATERIAL BROUGHT TO THE SURFACE BY THE EXPLOSION

and gun-paper by nitrating these substances. In 1847, an Italian man of science, Sobrero, treated glycerine with nitric acid, and produced nitro-glycerine, which won a tragic notoriety under the name of blasting oil. For it was a very delicate chemical compound, and it exploded with the least shock. Being liquid, it ran into the fissures of rock when poured into a borehole; and it required to be carefully confined when exploded by means of a simple fuse. Accidents occurred so frequently that the use of blasting oil was prohibited first in Belgium and Sweden, and then in Great Britain. A ship carrying some of the oil to Chili was blown up; and the event caused such a sensation that it seemed as though the use of nitro-glycerine would be entirely forbidden throughout the civilised world.

But a Swedish chemist, Alfred Nobel, solved in 1866 the problem of the high explosive. He mixed nitro-glycerine oil with a certain kind of porous earth, and produced a stuff somewhat like sawdust, which he called dynamite. Twice as powerful as gunpowder, and much more reliable, dynamite entirely revolutionised the science of blasting. It made possible the execution of the gigantic engineering work of our period, and it brought about that prodigious development of the mining industries of the world which has gone on since 1870. In fact, the invention of dynamite marked a new epoch in the history of civilisation. It enabled men to change, in a single generation, the face of the earth. By means of it he flung a network of railways swiftly over continent after continent; he removed mountains from his path; he mined for miles into the fiery heart of his planet; he brought oceans together by blasting away the rock and earth that sundered them: and, last of all, he threw aside his plough and all his steam machinery, and did his farming work with dynamite.

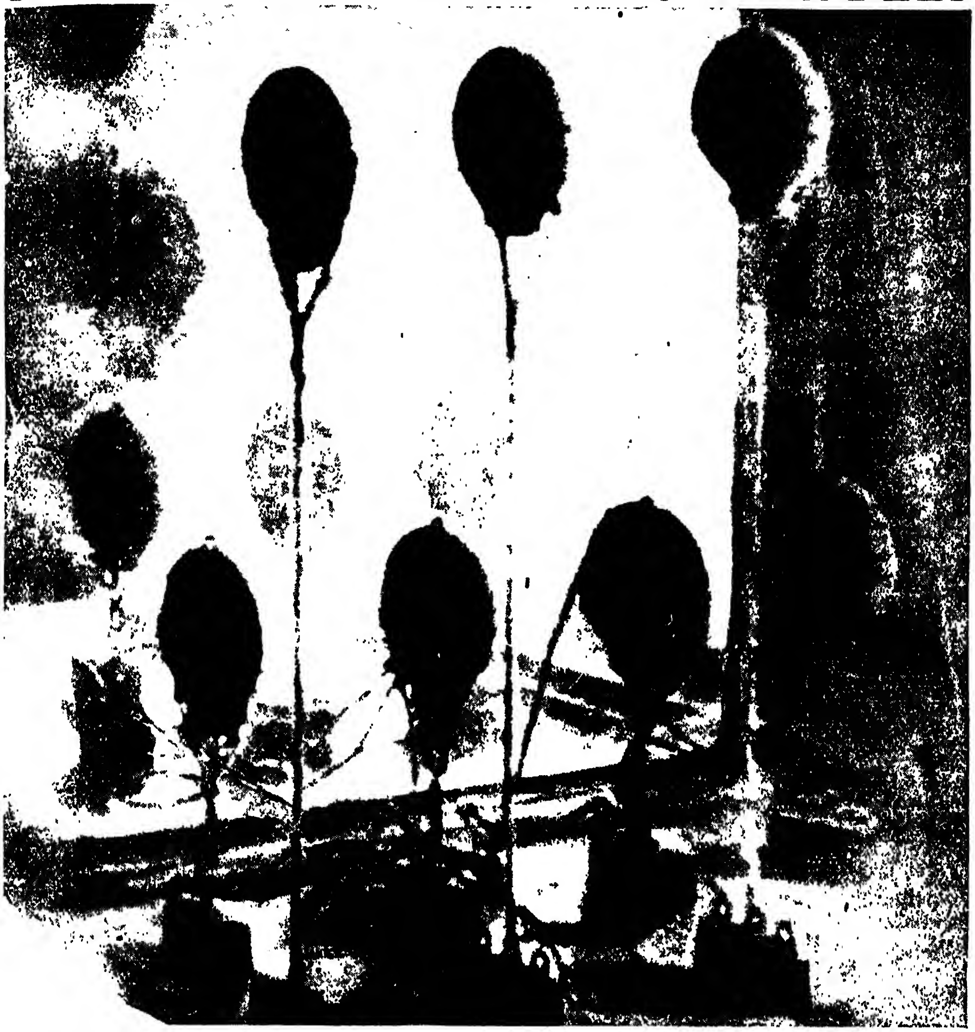
The man who invented this mighty force was weak of body and nervous of mind. But in spite of his weak frame and high-strung nerves, Alfred Nobel had a soul of steel. He feared no danger, and he yielded to no adversity. Most men would have succumbed under the misfortunes which befell him, but a succession of almost insurmountable difficulties did not deter him from pursuing his aim. The explosion of his factory caused a general scare and dread of the deadly compound he was making; the loss of his younger brother, to whom he was devotedly attached, so worked on his father's mind as to produce paralysis, and the mother was overwhelmed with grief and anxiety. But Nobel, with his extraordinary mixture of sensitive timidity and impulsive daring, went on with his perilous work.

MR. HUDSON MAXIM

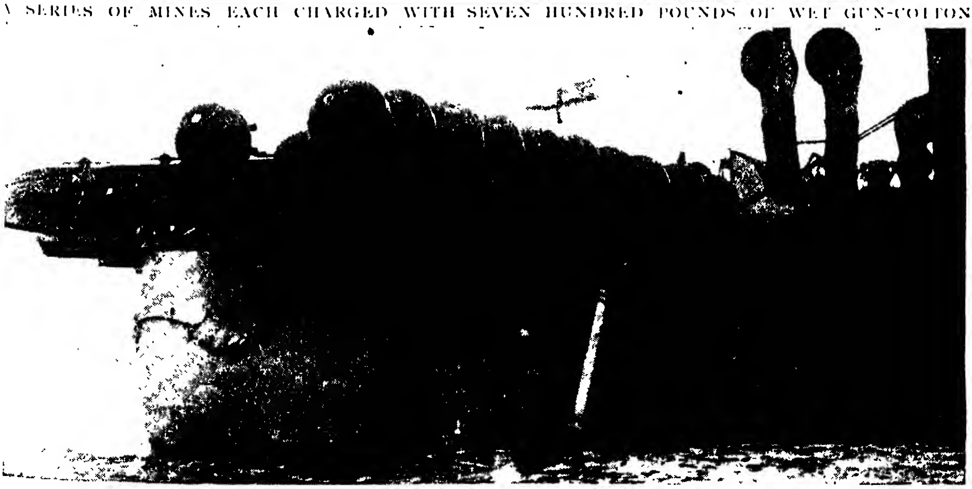
He was always ready to show how wonderfully safe his explosives were by handling them, though every time that any nitro-glycerine came into contact with his skin he was liable to headaches. These headaches affected him so violently that he was often compelled to lie down on the ground in the mine or quarry in which he was experimenting. But no pain quelled the courage of his soul, and he continually forced his feeble body to answer to his will. On one occasion, when some dynamite could not be removed from a large cask, he crept into it and dug out the explosive with a knife. Thus gradually by his example he taught miners and quarrymen to handle without fear the strange and terrible force he had discovered.

As a matter of fact, dynamite can be used as a torch to light a cigar. This used to be a favourite trick of Mr. Hudson Maxim. One day, to the horror of a visitor, he first lighted a cigarette with a stick of dynamite, then sawed the burnt piece off and used the remainder to cook a Welsh rabbit over a lamp filled with nitro-glycerine. The explanation of these terrifying feats is that most of the high modern explosives are different in action from gunpowder. Very great heat is required to

THE MAN SOWN DANGERS OF THE DEEP



A SERIES OF MINES EACH CHARGED WITH SEVEN HUNDRED POUNDS OF WET GUN-COTTON



MINES ON A WARSHIP IN READINESS TO BE DROPPED INTO THE SEA

set up the chemical reaction that liberates the gases. If lighted in the ordinary way, they merely burn like wood or oil. To explode them, a small quantity of fulminate of mercury is used; when this expands in gaseous form it exerts a pressure of more than half a million pounds to the square inch. The explosive wave it thus sets up is too strong to be resisted even by dynamite, and its gases expand with a smashing force.

In the ordinary way, dynamite may be kicked about and set alight, and even fired from a gun without exploding. So, too, a considerable quantity of gun-cotton may be set on fire, and it will then burn quietly. A torpedo filled with wet compressed gun-cotton will not go off, though a shell from a big gun penetrates the torpedo and bursts in the mass of gun-cotton. Even nitro-glycerine will burn like oil in small quantities, and a stick of nitro-gelatine may be lighted without danger.

Many persons, unfamiliar with modern explosives, fancy that shells and submarine mines and blasting compounds are dangerous in themselves, and that to handle any of them would be playing with death. But the fact is, the only ticklish part of the affair is the fulminating body, made by dissolving mercury in nitric acid, and adding alcohol to the solution. This is the "setting off," and when it is attached to a high explosive death is very close at hand.

INTERIOR OF A SUBMARINE MINE
The white space is occupied by the explosive, which consists of seventy-five lb. of gun-cotton

The real trouble with dynamite, from a modern point of view, is that it is not sufficiently explosive. It is safe, because a fourth part of it consists merely of absorbent earthy material which plays no part whatever in the generation of the gases. Formed of the remains of diatoms—a microscopic sea-plant with a hard shell—this material is inactive, and it takes greatly away from the power of dynamite. Knowing this, Nobel sought for some years for an active base for his nitro-glycerine compound. He wanted a substance which would dissolve in nitro-glycerine, and form a certain kind of chemical paste. Purely by accident he discovered what he wanted. One morning he was still experimenting in search of the new material, and he cut his finger. He sent a man out for some collodion to form an artificial skin to protect the wound. Having used a few drops as a liquid plaster on his cut finger, he was going to throw the rest away, when he thought of trying a mixture of collodion and nitro-glycerine. Collodion is made by dissolving gun-cotton in ether, and the solution so formed is used as a liquid plaster and a varnish and for photographic purposes. When combined with camphor, the dissolved gun-cotton becomes celluloid, now largely used as imitation ivory, and as photographic and cinematograph films. Only moderately strong nitric acid is employed in making this commercial kind of gun-cotton; it is often highly inflammable, but the camphor makes it inexplosive, and it can be worked with hammers and heavy rollers without any risk. By omitting the camphor, Nobel obtained a mixture of gun-cotton and nitro-glycerine which was remarkably safe, and yet remarkably powerful.

Only the accident of cutting his finger could have led the inventor to experiment with gun-cotton. For this explosive was the deadliest and most useless of blasting compounds. Gun-cotton contains too little oxygen for combustion. The consequence is that when it explodes it gives off poisonous fumes. Thus it was impossible to use it for industrial purposes. Nitro-glycerine, on the other hand, contains an excess of oxygen. So when Nobel combined the two explosives in certain proportions, the element that was wanting in one was supplied by the excess contained in the other. In other words, the quantity of oxygen-carriers in the compound explosive was perfect, and Nobel was able to produce, in 1875, a revolution in engineering and mining industries by means of his new invention of blasting gelatine.

The new explosive was half as strong again as dynamite, and it has been used recently in large quantities in piercing

DANGERS HIDDEN BY THE WATER'S SMILE

A SERIES OF SUBMARINE MINES EXPLODED

EXPLOSION OF 100 POUNDS OF GUN-COTTON

A ROW OF MINES EXPLODED SIMULTANEOUSLY BY ELECTRIC PRESSURE

mountains, like the Alps, where the rock is so hard that no satisfactory work can be done without it. Blasting gelatine is one of the most violent forces at the disposal of the human race. In its pure form it can be applied only to the hardest rock. Nobel, however, soon found a way of modifying its terrific action by adding saltpetre and woodmeal to the mixture of nitro-glycerine and gun-cotton. At the present time the use of dynamite has been entirely superseded in some countries by gelatine explosives.

The story of the discovery of some of the most terrible and yet tractable of modern explosive forces is full of surprises. It is also full of disasters; for it took men many years to learn how to control the manufacture of the mighty chemicals they were creating. Both surprises and disasters have been abundant in the application of the new high explosives to the purposes of warfare. It was long before gunpowder was displaced by the stronger nitric acid preparations in artillery. Even when blasting gelatine was reduced in power by means of moderated substances, it could not be made to fire a gun. So abruptly rapid was the creation of gases that they rent apart the steel body of the cannon, instead of using their force in driving the shell from the muzzle. Now blasting gelatine is made by adding about 8 per cent. of gun-cotton to warm nitro-glycerine. Yet Nobel found that if the amount of gun-cotton was increased from 8 per cent. to about 50 per cent., the mixture was suitable for firearms. It was an extraordinary discovery. One would have thought that by mixing, in equal proportions, the two most powerful shattering explosives, nitro-glycerine and gun-cotton, a compound would have been obtained that would rend and smash the strongest steel gun that could be made.

FIRING A 12-POUND GUN IN A GUN-PIT

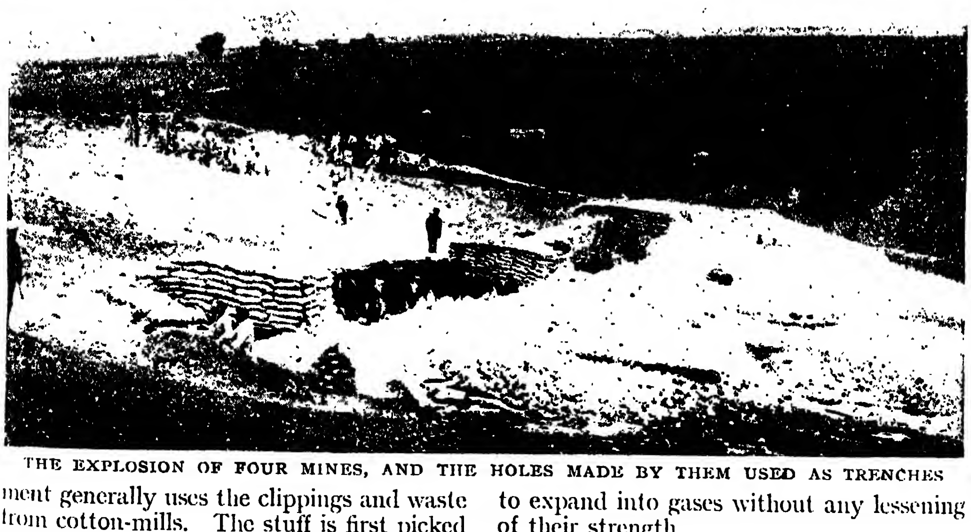
But, to the astonishment of Nobel himself the two mighty chemical forces modified each other, and produced a slow-burning powder that could be used even in revolvers. Far more powerful than any kind of gunpowder, the new compound revolutionised the conditions of warfare on land and sea. When fired, it produced no smoke to cloud the scene of battle, and it drove bullets and shells to a distance undreamt of by riflemen and gunners of the old school. It is by using the modified form of Nobel's mixture of gun-cotton and nitro-glycerine that we have been able to build the big naval guns that throw at every broadside more than five and a half tons of steel and lyddite twenty-one miles. And there has already been introduced a larger naval gun, the 14-inch, with a more terrific power of destruction.

The cordite used in our Services is a mixture of gun-cotton and nitro-glycerine; and, as originally made, it so resembled Nobel's invention that the Swedish inventor brought an action at law for the infringement of his patents. When Lord Justice Romer decided against him, he said some rather bitter things about British justice. The facts were that the men of science serving on the British Explosive Committee profited to some extent by the discoveries of Nobel, but they were afraid of using heat in the manufacture of the mixture. So they worked out a method of combining nitro-glycerine and gun-cotton at a low temperature by means of an acid. They produced

something that looked like a cord of gutta-percha, and varying in colour from light to dark brown; it was also slightly elastic, and they gave it the new name of cordite.

Practically all the high explosives used in modern guns and firearms consist of a mixture of nitro-glycerine and nitrated vegetable fibres. Cotton, wool, jute, and straw can be converted by means of nitric acid into explosives; and so can starch, sugar, coal, and treacle. Even manure has been made highly explosive. Our Government generally uses the clippings and waste from cotton-mills. The stuff is first picked over and cleaned from oil and grease and dirt, and then carded and cut into short lengths. After this, it is well washed and dried in steam-jacketed cylinders, about five feet long and one and a half feet wide. The dipping is done in cast-iron tanks, holding about twelve gallons of strong nitric and sulphuric acids.

The sulphuric acid does not add in any way to the explosive power of the gun-cotton. It is used merely as an absorbent, and for the same reason that a certain quantity of sulphur is added to the charcoal and saltpetre which are the active chemicals in ordinary gunpowder. When the compound is exploded, a certain amount of water is evolved by the chemical reaction. This water weakens the nitric acid in gun-cotton, and the saltpetre in gunpowder. If, however, some sulphuric acid or some sulphur is added, this takes up the water, and thus allows the real explosive elements to expand into gases without any lessening of their strength.

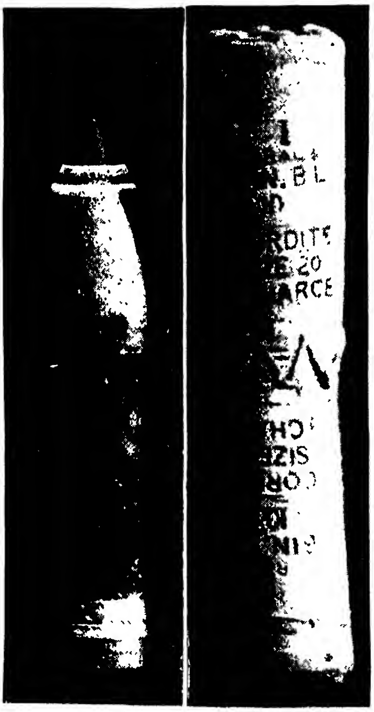


THE EXPLOSION OF FOUR MINES, AND THE HOLES MADE BY THEM USED AS TRENCHES

So the cotton is dipped in a mixture of strong nitric and sulphuric acids. It is thrown in the tank a pound at a time, and moved about by the workmen with an iron rabble. When thoroughly wet, it is lifted on to a grating above the tank, and there it is squeezed until it only contains about nine times its weight of acids. That is to say, a pound of dipped cotton should weigh ten pounds. The steeping process has then

to be carried out. The dipped cotton is placed in earthenware pots, which are set in rows in large cooling-pits, a foot deep, through which water is kept running. For forty-eight hours the cotton remains in the pots, and great care has to be taken to keep it quite cool. If all goes well, the chemical reaction is completed at the end of two days, and the cotton is entirely transformed into a new chemical compound, which is called nitro-cellulose.

Gun-cotton is one of the least dangerous of the nitro compounds to manufacture. It is often drained in a whirling machine that makes from a thousand to fifteen hundred revolutions a minute; and it is pressed by hydraulic power into blocks weighing a quarter of a ton, for use in torpedoes and submarine mines. A good many people now comb their hair with gun-cotton and handle it at all their meals. For, as we have already explained, two parts of liquid gun-cotton and one part of camphor form the celluloid out of which combs and knife-handles and innumerable other articles of daily use are manufactured. Yet when gun-cotton was first made in bulk, some dreadful explosions occurred in the factories for a little pressure was sufficient to detonate the compounds.



THE PROJECTILE AND CORDITE CHARGE OF A 6-INCH GUN

The manufacture of nitro-glycerine, however, is still a somewhat perilous operation. It is performed in a set of danger buildings placed in a danger area. The buildings are at different levels, down which the liquid explosive flows through lead-lined wooden pipes, from one house to another. No iron or steel or brick or stone is used in the construction of the danger buildings. They are made of wood, which offers much less resistance than hard material. Usually, when an explosion occurs, the sides of the house are blown out, and the roof goes up in the air and tumbles back on the blown-out walls. Had the explosion occurred in a strong brick or stone building, large fragments of the material would have been shot at the surrounding edifices. The best plan, it has been found, is to sink all the danger buildings in pits and surround them with ramparts of turfed earth, standing higher than the roof of the house of peril. In this way the effects of the disaster are confined to the spot at which it occurred. In nitro-glycerine works everybody must wear shoes of list or sewn leather, for nails are much more dangerous than lighted matches.

All persons must change their clothes before leaving the danger area. The nitro-glycerine gets into the clothing; and if a workman went home in his working dress, he would be a kind of walking torpedo, that might go off at any moment. All the tools are made of bronze or brass, and the buildings are kept together by wooden pegs or brass nails. Sometimes the buckets containing water that has been used to wash the nitro-glycerine will explode with considerable force, merely through the action of the sunlight that falls on them. So altogether a worker in a nitro-glycerine factory does not have a dull life.

Yet without him the two hundred thousand acres of desert land in America that have just been irrigated by the Roosevelt dam would still be a wilderness; the Panama Canal would not have been built; the United States would think of turning to Canada for bread for her vast and still growing population; thousands on thousands of miles of roads and railways now existing would still be waiting to be made; and coal and other important minerals would be less abundant and dearer in cost. In short, the entire industrial development of the world would have been seriously impeded, with the result that the population of the highly civilised races would have either been restricted in growth or compelled to adopt a lower standard of life.

The first stage in the making of the explosive takes place in the nitrating-house, which is kept scrupulously clean of grit and sand and dirt. Through a window in a large tank of lead, the operator watches

A POWER THAT REMOVES MOUNTAINS

BLASTING AWAY A HUGE MASS OF CLIFF AT FISHGUARD HARBOUR

THE DÉBRIS RESULTING FROM THE EXPLOSION SHOWN IN THE PICTURE ABOVE

a stream of glycerine flowing into a mixture of sulphuric and nitric acids. Under his control is a current of compressed air, that keeps the liquids well agitated during the process of nitration. A thermometer indicates the amount of heat produced by the chemical reaction, and it is this heat that the operator has to keep down. A constant stream of water circulates round the tank, and cools the mixture, and the current of compressed air also serves to lower the temperature. It takes about thirty minutes to complete the nitration; and when this is done the raw nitro-glycerine is ready to run to the separating-house.

On the Border-Line of Devastating Explosion

It is a heavy, oily liquid, of a pale straw colour, with a sweet taste and rather poisonous qualities. Some persons cannot let it touch their skin without getting a headache, and unless it is kept cool it is liable to explode. It flows from the nitrating-house to the separating-house. Here it becomes very dangerous. The separating-tank is also fitted with a window; and as the waste acids run away from the nitro-glycerine, a workman watches for the appearance of the vivid red fumes which are the danger signal. Whenever the smoke grows red, the pressure of compressed air must be increased to mix up the charge that is getting too hot through chemical decomposition. This decomposition is provoked by the water, with which the nitro-glycerine is washed two or three times. If the fumes cannot be kept down, and an explosion is likely to occur, the tap between the separating-tank and the drowning-tank is swiftly opened. The nitro-glycerine then runs away into the drowning-tank, which is a large cooling-cistern placed outside the house.

Where Boys and Girls Handle Dynamite as an Everyday Duty

But if all goes well, the charge, after being separated from the waste acids and well washed in water, flows down the leaden pipes into the large filter-house. Here it is drained through two flannels, and then drawn off in rubber buckets and tested by the chemist. Very often it does not pass the test, and has to be rewashed. When the chemist is satisfied with its qualities, it is poured down the pipe running to the settling-house. It stands in conical tanks three or four feet high, and remains in them for a day or more, to allow the water it contains to rise to the surface. Sometimes it is filtered through common salt, that keeps back the water, and thus shortens the time needed for the settling process; and at Waltham Abbey other ingenious devices to diminish the risk of manufacture, and obtain a highly purified chemical compound, are used, chief among them being the Nathan nitrator.

After the nitro-glycerine has settled, it is ready to be made into dynamite or compounded into cordite and blasting explosives. The dynamite is usually mixed by hand with a kind of earthy deposit found in Scotland, Hanover, and Sweden. It is then taken to the cartridge-huts, in each of which there are three girls. One works the press, which is a cylinder with an ivory cistern that pushes the charge into the cartridge. The other two girls wrap up the cartridges, and a boy comes at regular intervals to the hut—usually every ten minutes—and collects the dangerous product.

In the manufacture of cordite, the nitro-glycerine is combined with gun-cotton, and the two substances are compounded together by means of an acid. The result is a semi-fluid material, which is passed like macaroni through holes in a plate, so that it forms strings or cords of varying size, according to the diameter of the holes. Hence the name cordite.

The Relative Advantages of Cordite and Other High Explosives used in Gunnery

This famous explosive is a sort of compromise. It does much more injury to the big guns than the smokeless powder invented by the Frenchman of science, Vieille, and used in the French Army and Navy. It is reckoned that the wear on the big French guns is less than a third of the damage done to the rifling of our ordnance by cordite. That is to say, French cannon will be able to fire in a long and fierce battle from thirty to forty more shells than our guns.

The French powder is made of gun-cotton without any nitro-glycerine base. But it has the terrible disadvantage of being a very unstable compound. It decomposes, generating heat by its decomposition, and then exploding from the heat that it generated. Two great French battleships, the "Iéna" and the "Liberté," have been blown up through a cartridge of gunpowder igniting by decomposition in the magazines. At first it was thought by many Frenchmen that these disasters were the work of some malevolent Anarchist, but it is now known that powder B has a tendency to decompose and explode when it is more than four years old. If this fact had been known in 1898, there would have been no war between Spain and the United States.

FAMILIAR DEALINGS WITH EXPLOSIVES

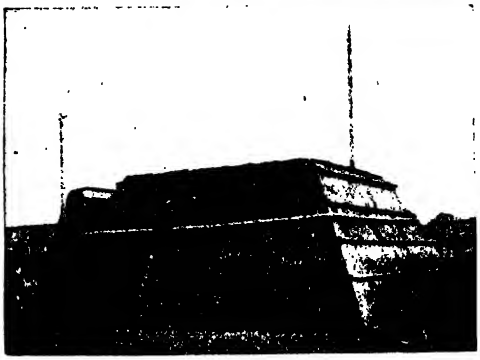

PICKING GUN-COTTON


MAKING FULMINATE OF MERCURY


MAKING DYNAMITE CARTRIDGES


WATCHING THERMOMETER DURING NITRATING


CORDITE STICKS OF VARIOUS SIZES


A TESTING-MAGAZINE IN INDIA

It will be remembered that on February 13, 1898, the American war vessel "Maine" was blown up in Havana harbour, with a loss of over two hundred and sixty officers and men. It was believed in America that the explosion was caused by a submarine mine placed by the Spaniards under the hull of the vessel, and a fierce and deadly surge of passion swept over the American people. But, much as they wished to take immediate war upon the Spaniards, they were unable so to do. For the naval ammunition available had been stored on the "Maine," and had gone with that vessel to the bottom of the sea. So, before America was in a position to fight, she had secretly to renew her stock of ammunition for her other warships. While treacherously blown up the "Maine." The war cost Spain much blood and treasure, and from her was taken her last of her great possessions in the New World which Columbus and his successors had given to her. Thus the Spanish empire which Columbus founded was scattered by a nation of settlers in the New World that he found. Yet, though America won the war, she, too, lost many lives and millions of pounds.

Had no disaster occurred to the "Maine," the dispute about Cuba might have been settled by the Spanish and American peoples without bloodshed. Last year the "Maine" was raised from the bottom of the sea by some American naval engineering experts. It was then found that the explosion had

THE DANGER-HOUSES IN THE EXPLOSIVE FACTORY OF MESSRS. NOBEL

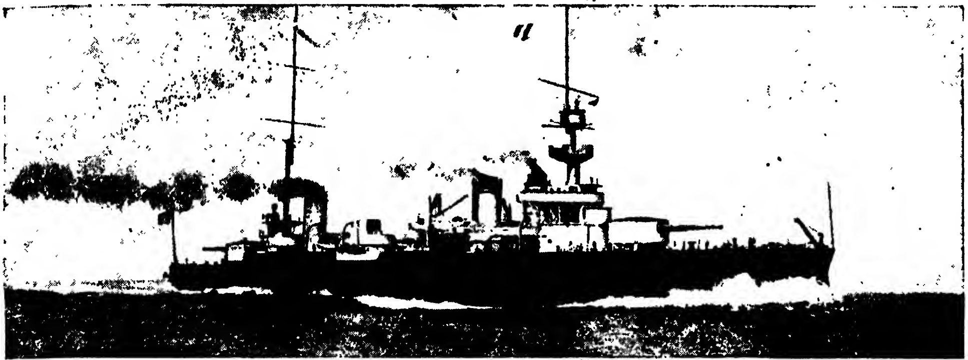
the explosives and shells were being privately manufactured, the American Ambassador in Spain went on conducting negotiations as though there was to be no war.

For six months this game of make-believe was carried on. At last the ammunition was ready. It was placed on a train and taken secretly across America: and there were few persons who knew why this one train was allowed to run its fastest speed across the continent, disarranging the traffic and holding up all the passengers using the lines. Rushed to San Francisco, the ammunition was put on the fastest ship available and hurriedly distributed among the American Fleet. Then war was declared by America, because it was believed that Spain had

occurred inside the ship. Some modern smokeless powder had decomposed and generated the heat that led to the loss of the battleship and over two hundred and sixty of her crew. So two great nations were driven into war through the mistake arising from the chemical instability of some of the high explosives used in warfare and industry.

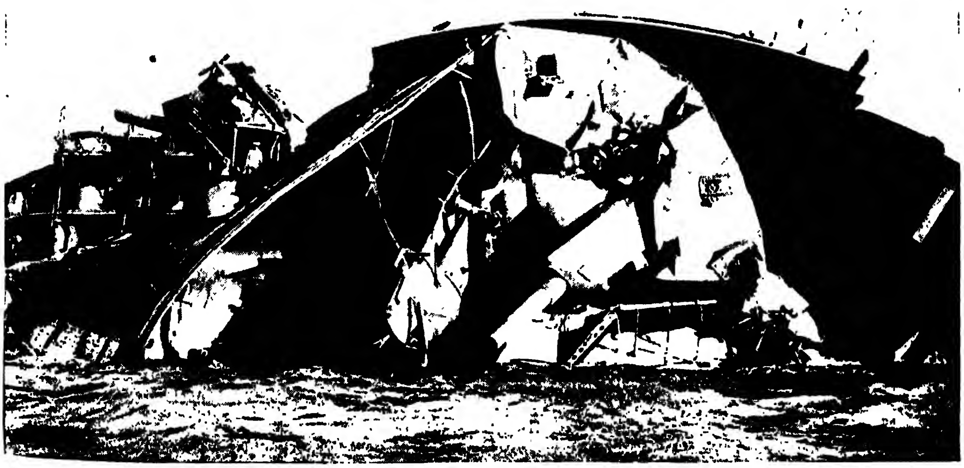
Great Britain is almost exceptional among the larger navies in having not lost a ship by the explosion of its own powder. The Japanese have lost two, the French two, and the Brazilians and the Americans one ship. We owe our good fortune to the care taken by the late Sir Frederick Abel and Sir James Dewar in working out the manufacture of cordite. For many years our

"HIDEOUS RUIN AND COMBUSTION"



THE FRENCH BATTLESHIP "LIBERTÉ," OF 15,000 TONS

THE EXPLOSION DUE TO DETERIORATED GUN-COTTON THAT BLEW HER UP



THE CRUMPLED WRECK IN HARBOUR AFTER THE EXPLOSION

The photographs on these pages are by courtesy of Nobel's Explosives Company, the Du Pont de Nemours Powder Co., the Great Western Railway, Enrique Muller, Stephen Cribb, Underwood & Underwood, and others

nation was pointed out as being behind the times, because of the large proportion of nitro-glycerine used in firing our guns. Nearly every other nation employed a dissolved gun-cotton preparation that developed less heat and did less injury to the bores of the big cannon. Now, however, Germany has adopted a propellant similar to our improved cordite for her big naval guns. For it has been found that gun-cotton powders are liable to be attacked by an organism which brings about the deterioration that leads to decomposition, but nitro-glycerine acts to a certain extent as an antiseptic. So, instead of being the most backward nations in regard to the science of war explosives, we are really the most advanced.

We prefer to wear out our guns quickly, and protect the lives of our fine sailors and the fabric of our magnificent battleships. We have had our warning, and have profited by it. About eleven years ago a cordite cartridge ignited on board one of our war vessels, but did not fire the explosives around it. And in 1906 the spontaneous ignition of cordite occurred in two places in India. On both occasions a dreadful disaster was averted by conspicuous acts of daring on the part of our soldiers At Haiderabad, officers and men rushed in and drenched the boxes of cordite which had been set smouldering by the ignited cartridge. At Ferozepore, our men removed, with cool daring, nine tons of black powder from a burning magazine, within a few feet of which were stored one hundred and thirty-five tons of explosives. Nowadays a heat-test, invented by Sir Frederick Abel, is used to check the deterioration of our cordite, and the cordite itself has been improved by compounding the gun-cotton and nitro-glycerine in a new and more stable manner. So, in spite of the fact that we have the largest Navy in the world, that carries its high explosives through all ranges of climate, we enjoy a remarkable immunity from disasters.

HOLE FOR FRUIT - TREE DUG BY DYNAMITE
It should be noted how dynamite has broken into the soil sideways, compared with packed condition of spade-cuts at top.

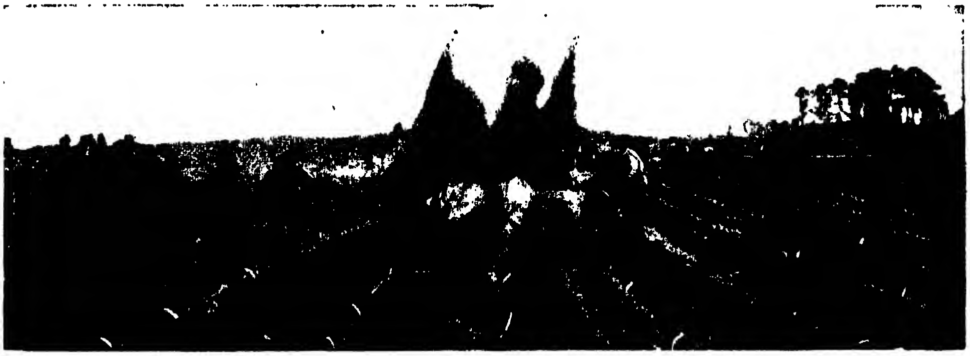
And more terrible than the cordite used in our guns and firearms is the picric acid explosive that is employed to burst the shells sent from our great guns. Picric acid is a coal-tar preparation, and for some years it was used as a yellow dye, with little thought of its terrifically destructive properties. But an explosion at a dyeing factory in Manchester drew the general attention to its enormously dangerous properties. It is often said that the Manchester explosion led to picric acid being studied as a detonating substance. But, as a matter of fact, Dr. Sprengel, one of the Fellows of our Chemical Society, demonstrated before Sir Frederick Abel at Woolwich testing-grounds in 1871 the wonderful explosive powers of the coal-tar preparation. Dr. Sprengel sent his article on picric acid to Eugène Turpin, of Paris, in 1884, and Turpin worked up the new compound into mélinite.

Mélinite is practically the same composition as the British lyddite and the Japanese shimose. One part of carbolic acid is added to eight parts of fuming nitric acid. This produces picric acid—a yellow crystalline substance of intensely bitter taste and great colouring power. It has been used as a fraudulent substitute for hops in bitter beer, but more generally as a yellow dye.

It was being used for dyeing purposes in Manchester in 1887 when the great explosion occurred. When picric acid is melted it looks like honey, and in its melted state it is combined with gun-cotton dissolved in alcohol or acetone, to form the bursting charge in the modern shell. Picric acid preparations have far too smashing an effect to serve as propellant explosives. They shatter any gun. But they can be placed inside a shell fired by a tremendous charge of cordite, and they will not explode until the shell strikes home, and sets off by its impact the fulminator attached to the blasting explosive. Then a yellow cloud of poisonous fumes arises, with a deafening report, and when the cloud thins away the face of the earth is seen to be changed. Trees are uprooted, and rocks ground to powder.

Some of the most powerful blasting substances used in mining and quarrying and tunnelling now contain a proportion of picric acid. The poisonous fumes are either burnt away by complete combustion, or else absorbed by some other substance. In modern blasting there is little danger when the men are careful; for all the explosives used for industrial purposes are

tested by our inspectors of explosives. Twenty shots are fired into a mixture of air and coal-gas. If none of these shots ignites the gaseous mixture, or leaves unexploded an appreciable amount of the charge, the Home Office allows the preparation to be used for blasting purposes in our mines. Usually, industrial explosions in mining and engineering are performed by a shot-firer, working an electric current from a safe shelter. Little is left to chance, for men have learnt by experience to control the tremendous force of the gases. This they do by boring shot-holes in the rock or coal they wish to dislodge—the depth and direction of the holes and the amount and the quality of the explosive determine, almost exactly, the nature and extent of the work performed by the fired charge. Some explosives drive a wedge through a hard material when they go off; others act like a tremendous steam-hammer, and deliver a smashing, crushing blow.

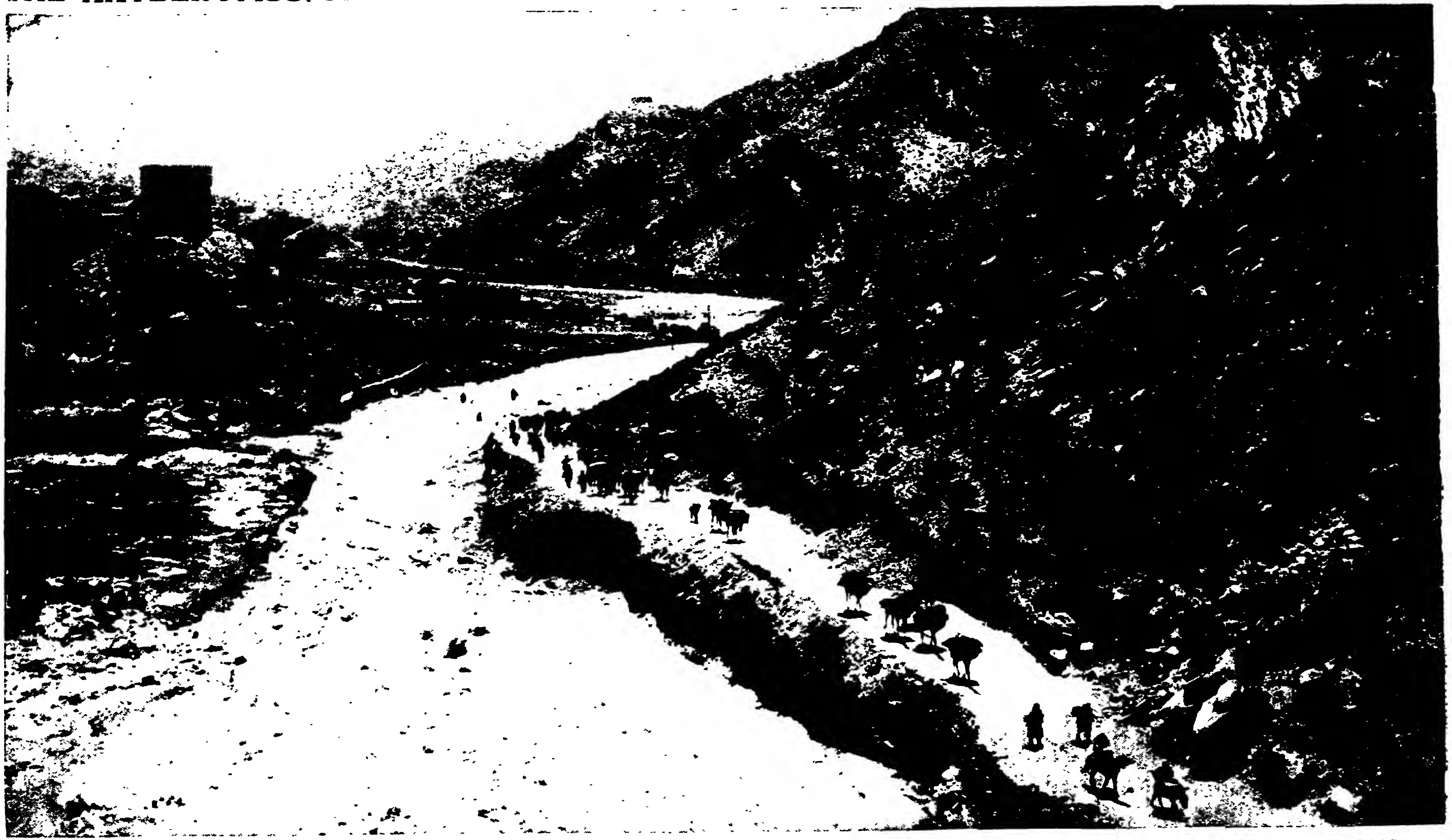


DEEP PLOUGHING WITH DYNAMITE IN AMERICA—LIGHTING THE FUSE

Dynamite is now seldom used in mining operations. It is less powerful than blasting gelatine, so a larger quantity is needed to produce a similar effect. It is also very dangerous where there is any firedamp, owing to the length and duration of the flame of its explosion. Lately, however, dynamite has found a new field of industry, in which it is producing some marvellous results. It is largely used in America for clearing land for tillage, and for making ditches and draining marshes. It is also used for ploughing. It will be remembered that a considerable part of the rich virgin soil of the United States was exhausted through the farmers taking crop after crop off it without putting any manure back into the impoverished earth. They found it more profitable to move to newly opened lands than to keep the soil in good heart. It was a selfish policy, and for some time it looked like ruining some of the most magnificent natural resources of the United States. Naturally, no one cared to farm land which had all the goodness taken out of it and required a great deal of money to be spent in fertilisers before it again produced a good crop.

It was here that the dynamiter intervened. Ploughing the land up with explosives, he brought to the surface a rich subsoil, which is now becoming a new and abundant source of food for the mighty and still expanding population of the country. Ordinary ploughing merely turns over the same soil year after year; dynamite breaks up the ground to a depth of five or six feet below the ploughing depth. Sometimes in well-nourished farm-lands 33 per cent. more corn to the acre is obtained by dynamite; while a worked-out farm can be made five times, and even ten times, more profitable by using about £2 10s. worth of dynamite on every acre of the arable soil, Orchard planting is also cheaply and quickly done by using dynamite to dig out the tree-holes. It even pays to explode small quantities of the explosive under old fruit-trees The reason is not yet fully known, for the increase in fertility is greater than that which could be effected merely by loosening the earth about the tree. We are inclined to the opinion that the dynamite kills off certain very minute animals which prey upon the microbes that supply the roots of a tree with various elements necessary to abundant fruitfulness. For certain market gardeners around London have found that heating the soil by means of a steam jet makes the use of manure unnecessary. As dynamite is cheaper than a steam jet, it seems highly probable that a great deal of the important work of modern agriculture will be done by means of the high explosive invented by Alfred Nobel.

THE KHYBER PASS, ONE OF THE WORLD'S GREAT HISTORICAL ROUTES OF TRADE AND WAR



A CARAVAN CROSSING AND RECROSSING THE RIVER, WHICH HAS BEEN THE ORIGINAL ROADMAKER, THROUGH THE NOW IMPROVED PASS

ROADS AND ROAD-MAKING

The Avenues of Trade and Travel on Foot and Wheel in Many Times and Lands

THE DUSTLESS ROADS OF THE FUTURE

NO settled country can reach a high state of prosperity without numerous and good roads. That is a sweeping proposition, but it can be advanced with confidence, though other means of internal communication have developed rapidly during the last century, and may seem to challenge the importance of the common highway. In some degree the railway admittedly has superseded the road; and in a few countries the waterway may almost be said to be the true road, though these latter canal-scored plains, quite manifestly, are exceptions. The rule is that while the railway makes a few roads comparatively solitary, it makes innumerable other roads additionally necessary; and so, more than ever, the high-road is the avenue to social and economic prosperity and an accelerated civilisation.

At once we grant that there are stretches on some of the world's great and renowned roads which fill the traveller on foot with a sense of sadness, so complete has been the triumph of the competing railway. The main traffic of the grandest of all European mountain roads, that over the Simplon Pass, is now carried burrowing through the warm heart of the mountain. The St. Gothard is only a little less lonely because its track is more open and valley-like. Even the Brenner, the great "German Road" of the Romans from Southern to Northern Tyrol, and at wider distances from Italy into Germany, is kept in good condition chiefly for strictly local uses, or for the touring motor-car visitor. And who now goes over the topmost section of the Arlberg road, from the little Vorarlberg State into Tyrol, though many be the travellers through the tunnelled crest? Or who crosses the crown of the Albula road, that leads so finely from the deeply cleft Grisons Canton into the lofty plateau-valley of the Engadine?

Nay, even in crowded England, before cycling and motoring gave "through" roads a new life, men were beginning to forget where the Great North Road really ran, alongside its deserted and dismantled hostelries, or the Holyhead road for Ireland and North Wales. In wider and less occupied lands the railway has made the overland line of pre-railway travel a memory. It has obliterated completely the prairie trail across the American continent; but then that never was a true road, but only a preparation for one. The traffic on the greatest road in the whole world, the Grand Trunk of India, a road that comes within reach of a hundred millions of people, has been somewhat thinned down by the competing rail.

Yes; we must admit that here and there a weakening of the supremacy of the great high-roads can be discovered; but the very success of the through railways has made the construction of subsidiary roads imperative, and has opened out country that before was barely accessible. The mileage of good roads increases enormously with the coming of the railway, which is not the competitor so much as the coadjutor and friend of the common road, and the advance agent of a civilisation that the bettered road will establish.

It is true there are admirers of the simple life who hold that the soundest prosperity may be found among the most sequestered peoples living nearest to Nature in her fastnesses, and furthest from an elaborate civilisation. We can imagine the simplicitarian objector saying: "Yes; but your fine roads, joining your fine railways, only bring into contact with an artificial world people who were happier in their remote, inaccessible, self-sufficing isolation than ever they will be when they know more of the modern world. Besides, England in her happiest days managed very well without roads; and

new countries prosper without them to-day. Indeed, road-making only belongs to two periods, wide apart in the world's history—the time of the Romans and the last hundred and fifty years. So, looking broadly over the earth and through time, do not the vaunted road-making eras shrink into rather small proportions ?"

Everyone who has sufficient knowledge to make a fair comparison between the condition of the peoples of remote mountain regions in Europe when they were first visited from without, and their condition now, knows that the beautiful simplicity of isolated communities, even when they live in the midst of favourable economic and scenic surroundings, is an armchair dream. Whether they be tested by health, cleanliness, morale, or social amenities, the people whose lands have been opened to intercourse with the world have improved; and the first agency leading towards that improvement is the valley road that makes travel easy. Any region will furnish a cheering comparison—the Dauphiny valleys, the Val d'Aosta, or Tyrol will serve;

Or, where the rude Carinthian boor
Against the homeless stranger shut the door.

Though the life of isolation may produce, sporadically, a few fine characters, its general effect has been stagnation, narrowness, superstition, hampering tradition; and the high-road that breaks up this isolation, in conjunction with the railway, is the avenue to higher pleasures and fuller ideals. The England of bad roads was the England of Tom Jones and Tony Lumpkin. And who would change from this to that ?

We shall refer in due course to the special case of the prosperous new lands that have no well-made roads.

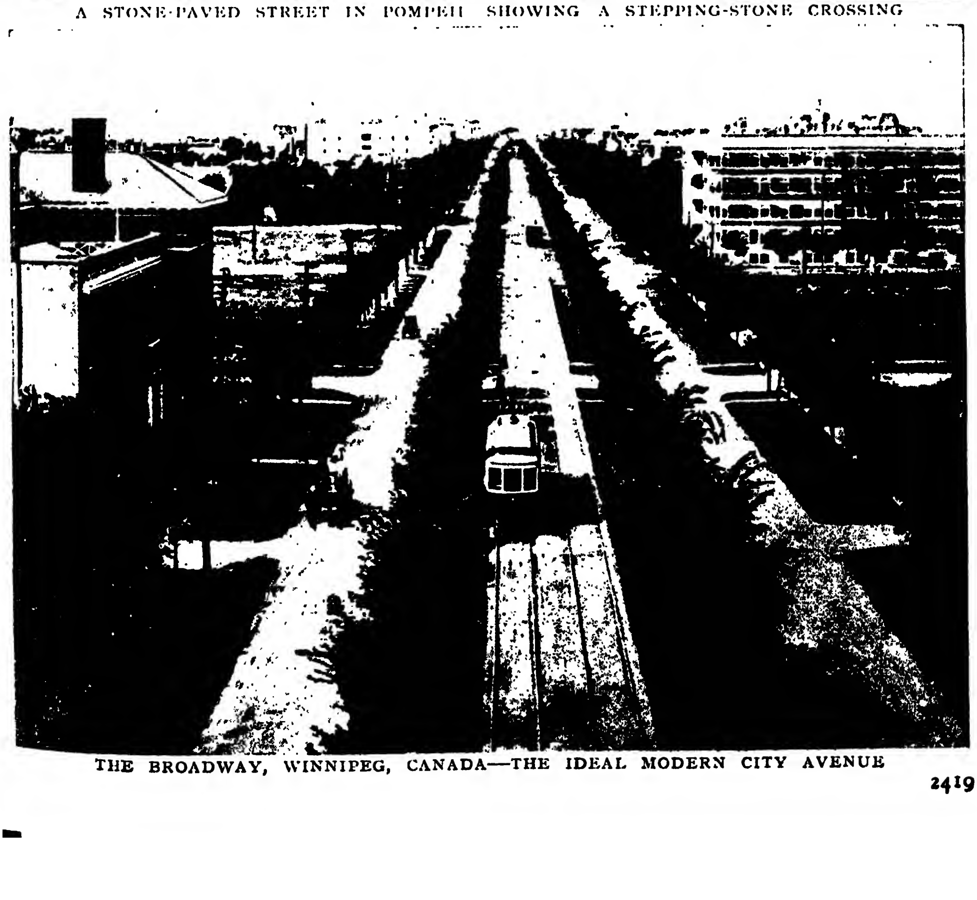
The historical division of roads into the few that are very old and the many that are quite modern—a product of the age of invention through which we are passing—is indeed striking, for it illustrates the extraordinary length of the period of industrial and mechanical stagnation between classical and modern times. The Romans did many things as well as the Western nations could do the same things until beyond the days of the English Stuarts; they did them as well, or better. Gunpowder was almost the only gain for fifteen hundred years; and many wise arts and practices, such as the maintenance of fine roads, were almost lost. Now all is changed; and the making of the modern road is an incident in the great drama of the mastery of space and time that has been proceeding so sensationally. It is indeed true that modern road-making is a matter of the last 150 years. John Macadam was born in 1756, and Thomas Telford in 1757; and anything like organisation of British roads was not begun till the days of their boyhood. But since their day road-making has transformed the world, and made comparisons with other times absurd. The countries that have not made roads are not in the modern period at all, as we see at once if we compare the highways of Great Britain and Spain. On the average, in equal areas, the British Islands have twenty-five times as many miles of roads as Spain.

The history of the highway is a story in four chapters. First, it is the story of the man who walks; next, of the man who

ROMAN ROADS IN USE TODAY IN ENGLAND
The causeway over Stanage Edge and a three-mile stretch near Dorchester

ROADS OF THE OLD LANDS AND THE NEW

A STONE-PAVED STREET IN POMPEII SHOWING A STEPPING-STONE CROSSING



THE BROADWAY, WINNIPEG, CANADA—THE IDEAL MODERN CITY AVENUE

rides a horse; then of the man who uses a wheeled vehicle depending on animal draught; and, lastly, it is the story of the man who rides on or in other forms of wheeled conveyances. We think now almost entirely of these two last modes of movement, but the others are behind them.

The first roads were tracks, footpaths, trails; and they were designed chiefly to keep the traveller out of wet places. One may see the process still in any moorland district, and in many a winding country lane. Can it be that the sentiment that surrounds a foot-track, anywhere, everywhere, among the rocks, across the dry shoulder of the hill, and over the gap into the next valley, or even along the stile-barred field-path—can it be that that sentiment is an unconscious reversion to the primitive days when the single-file track was the only road? Half the charm of the country, whether we wander through bypath-meadow, or wind our way through the woods, or climb the fells in the shepherd's footprints, comes from the faint romance of the foot-road. The instinct of the African following his forest track from the coast to the interior, or the Indian of the New World traversing the wood that is trackless to the stranger, or the mountaineer who walks with eyes that trace a way ten miles off, lives in a dim way in almost every man—a scarcely heard racial echo from the primæval world.

Nor is the bridle-path, the next stage in the evolution of the road, deprived of sentiment. One feels it when one stumbles upon the deserted packhorse track across the moor, and pictures instinctively the cavalcades of the vanished years; nay, one even feels it when in the mountains short cuts of the old mule-path are taken while the tame road with the diligence winds smoothly and slowly below us. The energetic and educated little countries—such as Switzerland and Norway—have fully realised, as backward countries like Spain and Turkey have not, that the road for wheeled traffic is indispensable; and the mule-path or bridle-road is becoming a romantic inconvenience, that only satisfies the parts of the world still slumbering under Spanish or Turkish semi-civilisations.

A SURVIVAL FROM ROADLESS TIMES—MULES CARRYING STONES UP A ROUGH TRACK AT SORRENTO

Rather curiously, some of the most prosperous lands on earth are but slowly beginning to understand the true place of the road in a national economy. The conspicuous examples are the United States and Canada. There, speaking broadly, true road-making is just being found out; and, to a considerable extent, the discovery is made through the motor-car. As the multitude everywhere found the meaning of the term "gradient" through the use of

THE IMPROVEMENT OF AMERICAN ROADS

A ROAD THAT WAS TYPICAL EVEN IN THE OLDER STATES OF AMERICA

THE SAME ROAD AS IT HAS BEEN IMPROVED BY SCIENCE UP TO DATE

Partly through what they see in travel, partly through the use of the motor-car, and partly through the general advance of science, the American people are beginning to realise the need for good roads, and are undertaking their construction on a large scale. The above illustrations, from Massachusetts, show the nature of the changes.

their muscles in working the bicycle, so the wealthy everywhere realise practically what a road should be when they begin to scour the world above the adhesive wheels of a costly motor-car. These prosperous, flat, agricultural, new countries got on very well without any roads worth mentioning, except in the great cities and long-settled districts, until they wanted to swim through the air at thirty-five miles an hour on a motor-car. Nothing strikes an emigrant, or visitor, from the Old World to the New so swiftly on entering, say, Canada as the makeshift character of the roads. It is so even in cities like Quebec and Montreal. Only the main streets are streets at all, judged by their paving; and the native-born are blandly unaware that anything is wrong.

The explanation is simple and complete. Until a town, or city, is sufficiently organised to be able to afford a debt, it does not admit of the need of a road. It suffices to leave a wide strip of the plentiful land, in its natural state, where vehicles may pass. When part of this common passage across the ordinary soil becomes rutted and water-logged, vehicles pass somewhere else on the broad track, until the whole of the future site of the street is like the entrance to an English ploughed field when the season for carting manure is ended. Meantime, the inhabitants walk on plank "sidewalks." Presently the city develops till it can borrow money for public improvements, and then road-making begins. This is the story of the last ten years in such fine rising cities as Brandon, Regina, Calgary, and Edmonton; and it was the story of Winnipeg a little earlier — Winnipeg, which now has two of the most spacious streets in the world. The fact is that road-making must always come at a late period in economic organisation, and be a co-operative effort.

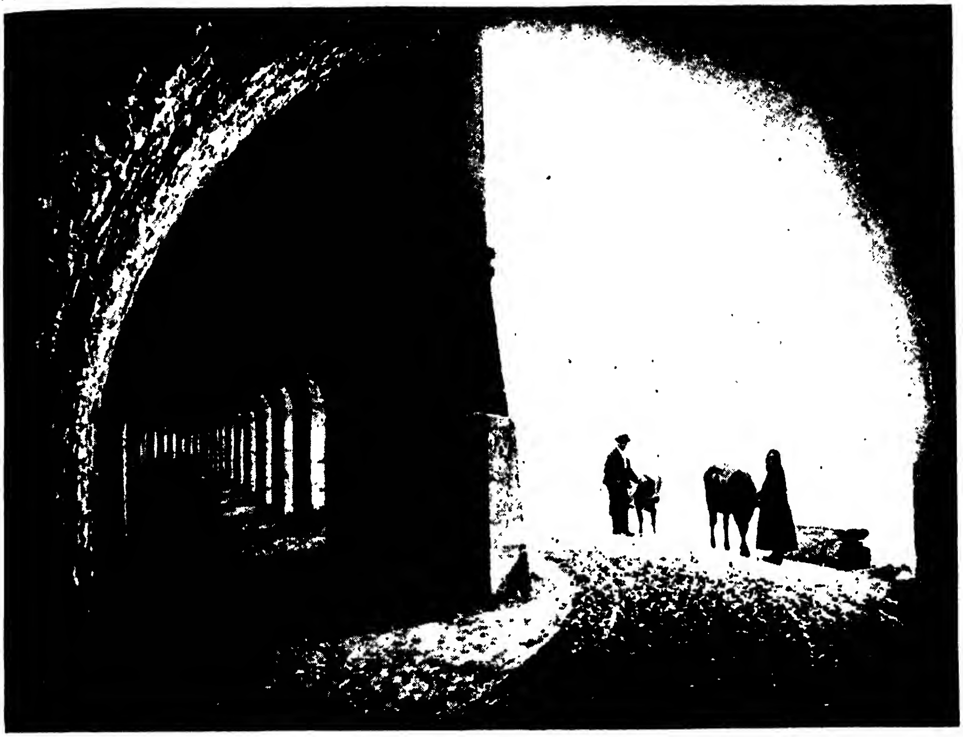
The problem When should roads be made? begins with their first need in virgin country and continues after the latest Act in town planning is put into force. The whole prairie area of Canada, for example, is surveyed for roads; that is, the country is laid out in townships of six miles by six, with spaces allowed for broad roads, at right angles, every mile, the roads-to-be running north and south and east and west. The diagram of a township on page 2426 shows the arrangement by which Canada leaves room for its roads of the future—a broad road surrounding each square mile, and a narrower road intersecting each square mile (640 acres), and dividing it into quarter sections of 160 acres—that size being the unit of Canadian farm occupation. Thus, every farm has a possible road on each side of it—open prairie staked out and left for a road.

JOHN LOUDON MACADAM

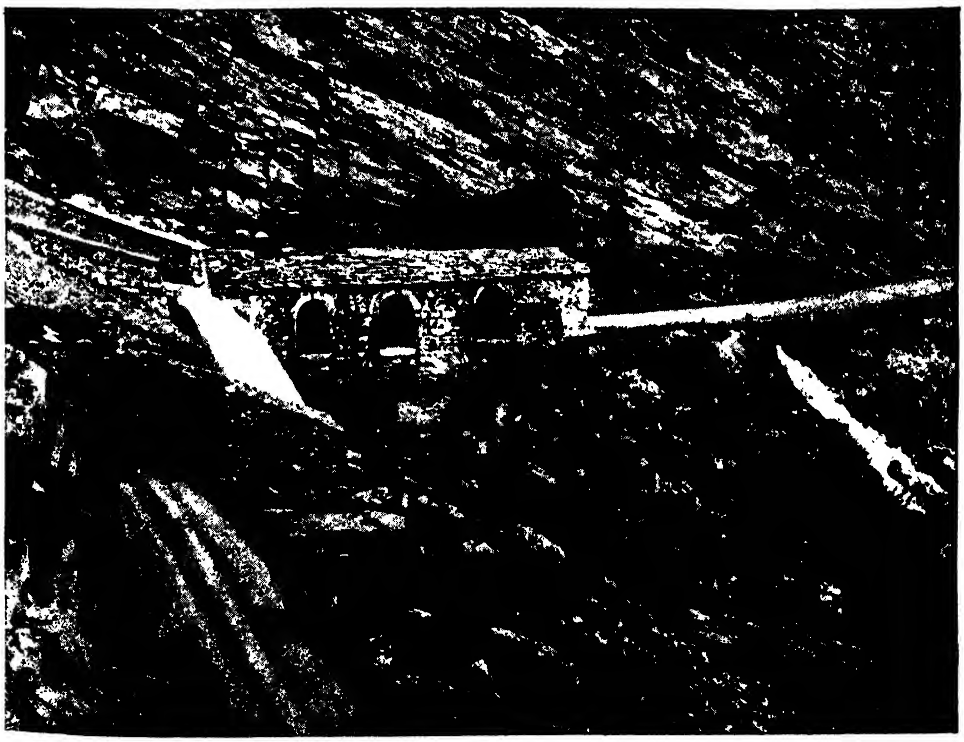
In the English town, where land is the chief expense, the serious problem arises, as estates are laid out for building, shall the roads be first prepared as a prime necessity, or shall the houses be first built, and the roads be allowed to come into being, as avenues with a sound surface, with such slowness or swiftness as the complaints of the inhabitants, or the energy of the local authority in putting pressure on the owners of the adjoining houses and lands, may determine? In Germany the preparatory system prevails, and if houses are to be built satisfactory roads are made beforehand. In England, chance, modified by pressure and agitation, is characteristically preferred, on the ground that capital cannot be spent reasonably on roads until profits are being made on the houses adjoining such roads. In fact, we follow the Colonial plan of waiting for the well-made road till press of population makes it inevitable, and, from the point of view of capital, easier to construct. The more thorough German thinks that, as there must be a road, it is better to have it made beforehand, and so secure sanitary advantages and convenience of transit from the moment the new houses are in use.

The Roman, the first great road-builder, worked with a much clearer idea of the

SHELTERED ROADS ON SLIDING SLOPES



THE SUMMER AND WINTER ROADS OF THE SNOW-SWEPT SIMPLON



A TUNNELLED ROAD ON THE SIMPLON PASS, WITH OVERBORNE STREAM AND SNOW-SLIDE

true value of the road. He saw far ahead, and knew the folly of holding off from spending as long as possible. He drove his roads to the furthest limits of his empire, and made them to last all time. The result is that some of them have been in use over two thousand years. The Appian Way, known to all visitors to Rome, was made in the year 313 B.C., and so has been serving mankind for twenty-two and a quarter centuries. We know of nothing else made by man that has served him so long.

A present view of the Appian Way does not, however, tell us what it was like in the far-off past. Only in two respects does it preserve its ancient features necessarily. Those two are its straightness, and an impression of narrowness! The ruins of the tombs that flank it show that it must have been narrow. Indeed, it was narrower than it looks. Roman roads, though built with such foresight and thoroughness, were always narrow. They were so in this country, even where they now appear in the midst of a wide roadway track. Existing as roads all through the turbulent centuries since their formation, they have been widened on either side of the carefully prepared surface, in order that the traveller might not be pounced on suddenly by lurking enemies. Indeed, there was once an English regulation that the main highways should be two hundred feet wide. That is how we get the fine open sweep of the great "through" roads; but the true Roman road was quite narrow, and only two conveyances could pass at once. The paved part, even on the Appian Way, was but fifteen feet wide, and there was a drainage trench on each side that would make careless driving undesirable. The dominant feature of the road, unfamiliar to us now, was the paving—a closely cemented level flooring of flagstones, making an absolutely stone road, that rested on a foundation of prepared stone or concrete, nearly a yard thick. In short, the surface of Roman roads was like the hardest of town pavements of the present way, as smooth and as regular. It was a causeway for vehicles, with narrow walks on either side for foot passengers.


THOMAS TELFORD

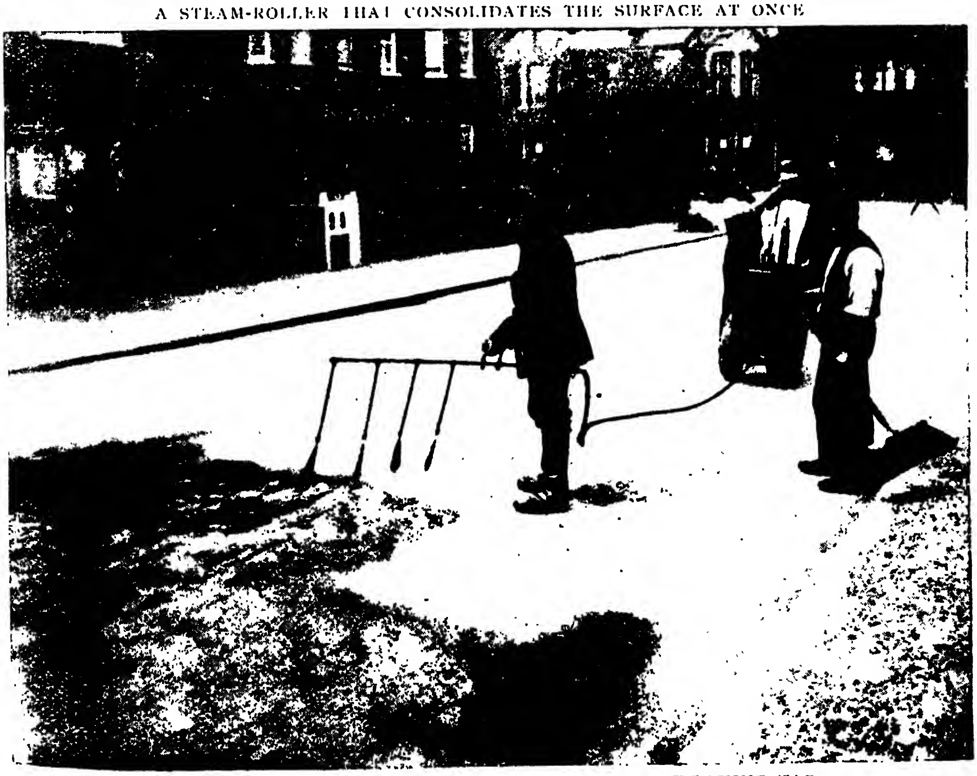
In making it, a trench was cut on each hand, the soft earth removed, and the under layers bedded hard by ramming; then several courses of flat stones were laid in mortar; above this a course of rubble masonry or concrete was added; next, a final layer of concrete, and on the top blocks of stone were carefully fitted and jointed. That was the ideal Roman road—really a great smooth causeway of masonry in the neighbourhood of the cities, and exceedingly substantial in the country wilds, as may be judged from such remnants as are left after fifteen to seventeen hundred years of waste.

A great deal of ingenuity has been expended in tracing the various Roman roads that once crossed England in all directions, but the details are hazy in many places, partly owing to the number of subsidiary or cross roads even in Roman times, and also to the altered economic conditions that existed when our modern road system was evolved. These conditions led to an abandonment of the old straight, narrow highways which made direct for far-distant points, that, later, were of diminishing importance, and to the formation of new roads serving local conditions and gathering towards more modern industrial centres. Broadly, we know that Roman roads passed from Dover through London to Chester, and thence to Carlisle, York, and Newcastle—the old Watling Street; from Bath through Leicester to Lincoln—the old Fosse Way; from London to Lincoln, with branches to Doncaster and York—the old Ermin Street; and from Norwich to Dunstable and Southampton, and probably on to the distant west—the old Icknield Street.

But these good roads—never probably commodious enough for the wants of a considerable population exchanging its goods at great distances—had become a

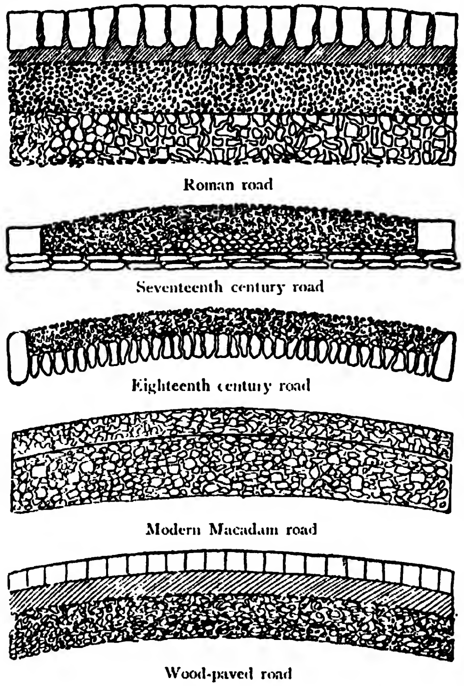
SURFACE-MAKING BY MODERN METHODS


A STEAM-ROLLER THAT CONSOLIDATES THE SURFACE AT ONCE


APPARATUS FOR GIVING A TOP-DRESSING OF DUST-LAYING TAR

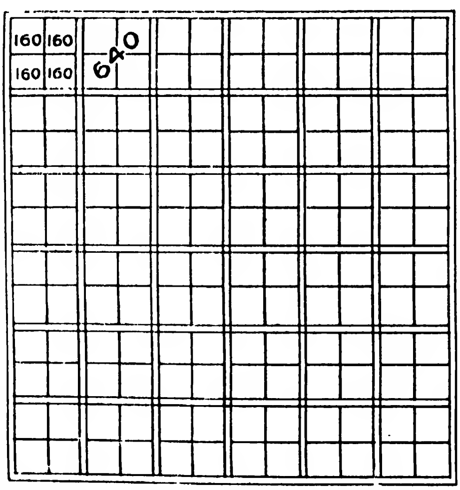
faint tradition by the middle of the eighteenth century, when England began to grow towards an industrial future; and every reference one can find to roads at all is a bitter complaint, even in the days when wheeled traffic was a rarity. A journey for many hundreds of years was a genuine adventure; and prayers were needed for all who travelled by land quite as urgently as for all who travelled by sea. So much was this the case that road-making and bridge-building ranked high as religious duties. Indeed, in the twelfth century a religious order, the Pontife Brothers, was founded on the Continent for the purpose of bridge-building. It was possible in those days to obtain partial remission from purgatorial fires by repairing the "wicked ways" of the vicinity where one lived; and some who built bridges—like Hugh of Clopton, who built the bridge at Stratford-on-Avon—earned for themselves, owing to other local circumstances, a nominal immortality. So bad were the English roads in the fourteenth century that the meeting of one of the Parliaments of Edward III. was delayed specially to await the coming of the members, owing to the badness of the ways and weather.

Out of this state of chaos our country began, slowly and experimentally, to bungle its way, in the middle of the eighteenth century, by the formation of turnpike trusts. The trusts were established by law to make district roads, which they had power to bar with gates and so levy tolls; and besides these roads the separate parishes could make their own roads, and lay rates on the inhabitants. A worse system could not well be imagined than that of turnpike trusts, which placed the whole road traffic of the land at the mercy of innumerable little, incompetent bodies; but by sheer pressure of circumstances and dint of complaints the main roads were gradually improved.



DECLINE AND REVIVAL IN ROAD-MAKING

The originators of the modern road-making systems were two Scotsmen—John Loudon Macadam, who was born in 1756, and died in 1836; and Thomas Telford, born 1757, and died 1834. Though there have been improvements on their plans, and modern conditions of traffic need fresh modifications of construction and upkeep, these men were the practical pioneers of the sound roads of the chief European countries. It is true that Mr. Edgeworth, the self-opinionated father of Maria Edgeworth, the novelist, had published an essay on he subject, which preceded the work of Macadam, and, as theory, may deserve some credit.



CANADIAN ROADS A MILE APART, AS SURVEYED ON A PRAIRIE TOWNSHIP

Before Macadam revolutionised the practice of road construction, there were long periods of distorted ingenuity in spoiling good ideas. Admittedly, for example, a flat road is not a good road. Some slope for drainage is advisable, both ways from the crown of the road; and it is better that there should also be a lengthwise rise and fall in a road than that it should be dead flat. It is easier for horses, and better for

LAYING A LONDON WOOD PAVEMENT

ALIGNING WOOD BLOCKS AND TARRING THE CREVICES BETWEEN FOR SOLIDITY AND COHERENCE

SPREADING SAND OVER THE TAR TO FORM A ROUGH AND ABSORBENT SURFACE

getting rid of the wet, which is the arch enemy of the highway. The common mistake of the surveyor who only knows a little is to make the crown of the road too high; and this mistake was generally exaggerated in the days before Macadam, with the result that vehicles all sought, and kept, the crown of the road, which in consequence was quickly worn into ruts that became water-traps.

Macadam insisted that it was unnecessary to have the elaborate stone foundations which the Romans had used, and that a good, smooth, hard surface could be maintained by spreading, ten or twelve inches deep, stones that had been broken into angular forms of such a size as to pass through a 2½-inch ring. The angles, he held, would fit and bind together. His system proved a great and general success, its weakness being that it necessitated a very uncomfortable period when the broken stone was first placed on the road, which became little better than a stone-heap.

Telford, who began the construction of roads in the year 1803, paid much attention to gradients. His variation from Macadam was that he laid a foundation of large stones, with sufficient spaces between to allow of drainage under the road. Above this rough and strong foundation he placed broken stone, like Macadam, decreasing its size up to the top, so as to avoid the roughness of Macadam's surface. Mr. Edgeworth had advised the filling of the interstices with gravel or sharp sand; and now all these plans are combined, with the addition of consolidating the material by using a heavy steam-roller, so that the surface, which has been sanded and watered, is made comparatively smooth at once. A good, up-to-date road, then, has commonly a Telford foundation, a Macadam centre, and a more modern crushed, sprinkled, and often tarred surface.

Of course, the roads of a district depend to a considerable extent on the local material available. That is in part determined by cost, and sometimes by local prejudice. It is difficult to persuade a parish, for example, that its stone is not as good as any other variety; and so, usually, the roads in country districts are a fair index to its surface geology. Recently a much wider view is gaining ground; and the National Road Board is likely to bring our main roads, at any rate, into good order on a national scale—an aim that is made imperative by the use of the motor-car, which treats a whole country as the parish of the motorist. He, by the way, is the chief wearer of the roads, for since motoring has became general the cost of upkeep has increased by from 30 to 70 per cent.

THE DUST PROBLEM—A RACING CAR PASSING FROM A PREPARED SURFACE TO DRY MACADAM

Over a considerable part of the world stone is not available for road-making; and all kinds of adaptations must be studied, such as the charcoal roads of forest districts, and the cinder roads of coal-using regions; but wood, next to stone, is the favourite material. It takes the form of logs in well-wooded regions, with faggots or brushwood as a basis in boggy bottoms; and even to the present day, on English moorlands, heaped up, or barrelled, roads may be found made largely of heather and turf mixed with stones.

The material for a road in urban districts is chiefly determined by the amount and character of the traffic, and by the gradient. Where heavy vehicles slowly move great weights, as in the neighbourhoods of docks and manufacturing firms, granite setts are usually laid down, on cement concrete, the cost being from thirteen shillings to fourteen shillings per square yard. But then the average life of such a workaday pavement is twenty-one years—a term that reduces the cost to cheapness.

The principal quarrying centres for these setts are Aberdeen, Cumberland, the Charnwood hills of Leicestershire, Norway, and Wales (Pwllheli). The faults of granite as a

paving material are its noisiness and, in hot weather, its slipperiness. The syenite of Charnwood — Mountsorrel, Bardon Hill, Markfield, and Whitwick—is remarkable for endurance, but cannot be used safely when the gradient exceeds one in forty. On severe gradients gritstones and limestones are used in towns, a gritstone being more suitable even than macadam for a steep street, as the flood waters in such a position wash away any macadamised surface and silt up the drains.

For the business part of towns and cities, wood paving or tar-macadam, varied as asphalt, has become almost universal, because of its cleanliness and noiselessness. The cost of a redwood paving, of six-inch blocks, is from eleven to twelve shillings per yard, and the average life of the road seven or eight years in a busy thoroughfare. This is a higher cost than the softer varieties of non-slippery stone, but the life of wood is somewhat longer than that of such stone. Tar-macadam costs from four to five shillings per square yard, including a rubble foundation, and its time in use is about half that of wood, and one-fifth that of granite.

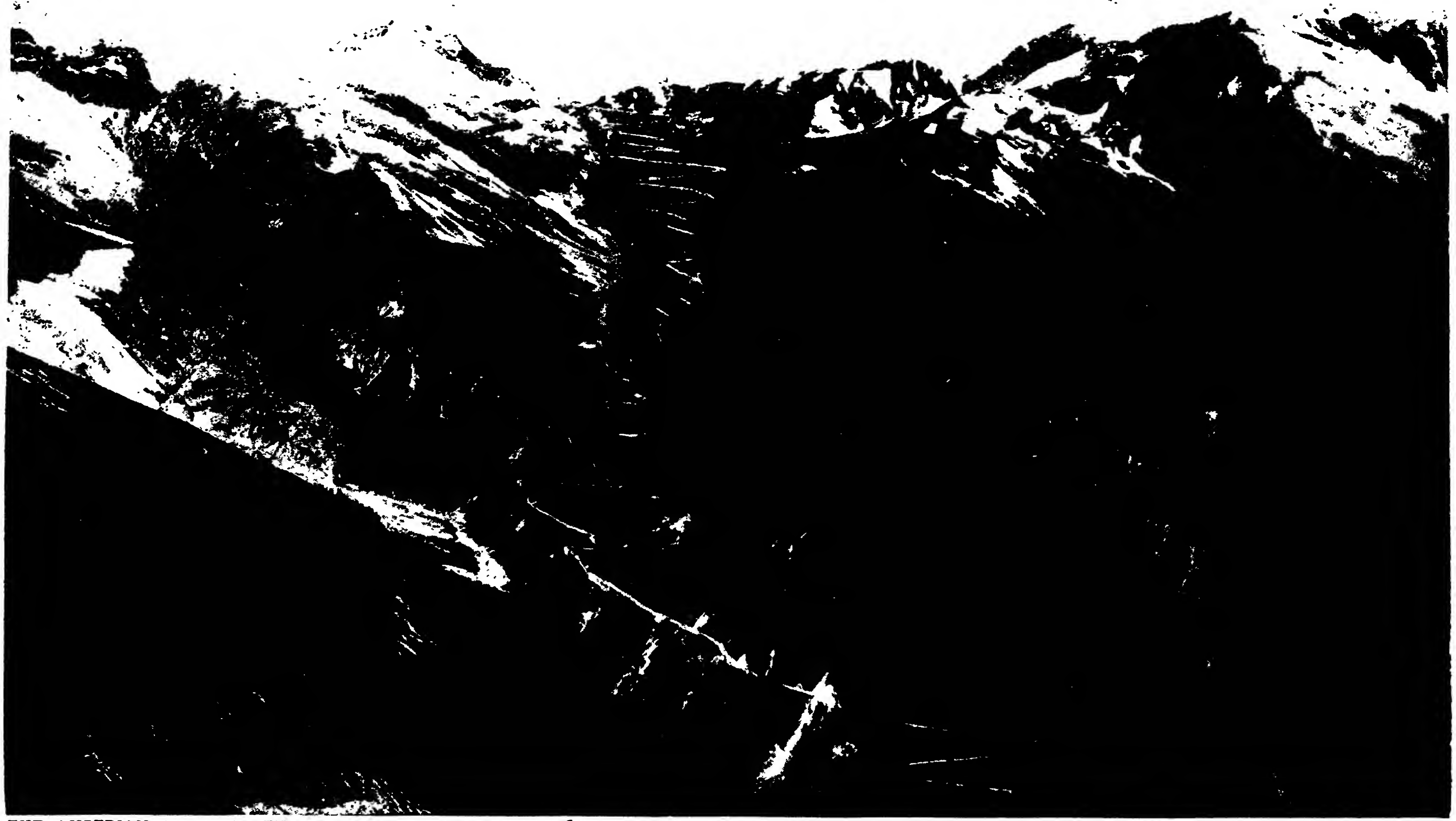
A MODERN METHOD OF ROAD-MAKING—A ROLLER AT WORK ON TAR-MACADAM

Nonetheless, the tar-macadam road, or rather a macadam foundation with a bituminous binding on the top, frequently renewed, seems to be the road of the future, until chemistry invents a dustless surface-preservative that has less stickiness than tar. It has been found that a light dressing of a bituminous mixture will not only make a well-rolled macadam road quite dustless under motor traffic, but that the preservation of the surface of the road more than repays the cost of materials and labour when compared with ordinary renewals; and there is therefore no economic reason why all main roads should not be smooth and practically dustless under motor traffic.

The latest revival of the road in civilised countries began with the bicycle—a vehicle that has had an enormous effect on social relations, particularly by widening the range of women's interests, amusements, and sphere of self-reliance. And the motor-car, and petrol carriage for the conveyance of goods, have continued the revival and have shown the directions that progress must take. The road of the future will provide for several distinct uses. The pedestrian must have his rights preserved by means of a footpath free from dust. The vehicular traffic by animal draught must be respected, and have its fair share of accommodation, and the motor machine of every kind has a right to demand a clear course of dustless road, so that it may be freed from the odium of creating a grievous nuisance. In short, we are only at the beginning of the science of complete and adaptable road-making.

That science is now seen at its best in the two extremes of city life and mountain solitudes. The paving of many of our great cities with wood, asphalt, tar-macadam, dry macadam, gritstone, or granite, according to the varying requirements of gradient, traffic, and cleansing, is an example of masterly engineering and adaptation. London, in particular, is admirably served, so far as road surfaces are concerned. At the other extreme are the magnificently engineered roads of the mountainous countries. Some of the greatest of the Alpine roads were made, it is true, for military purposes, but they are kept up at heavy cost for peaceful ends, now that the original reason for their construction has disappeared. Thus the great road over the Stelvio Pass, or Stilfser

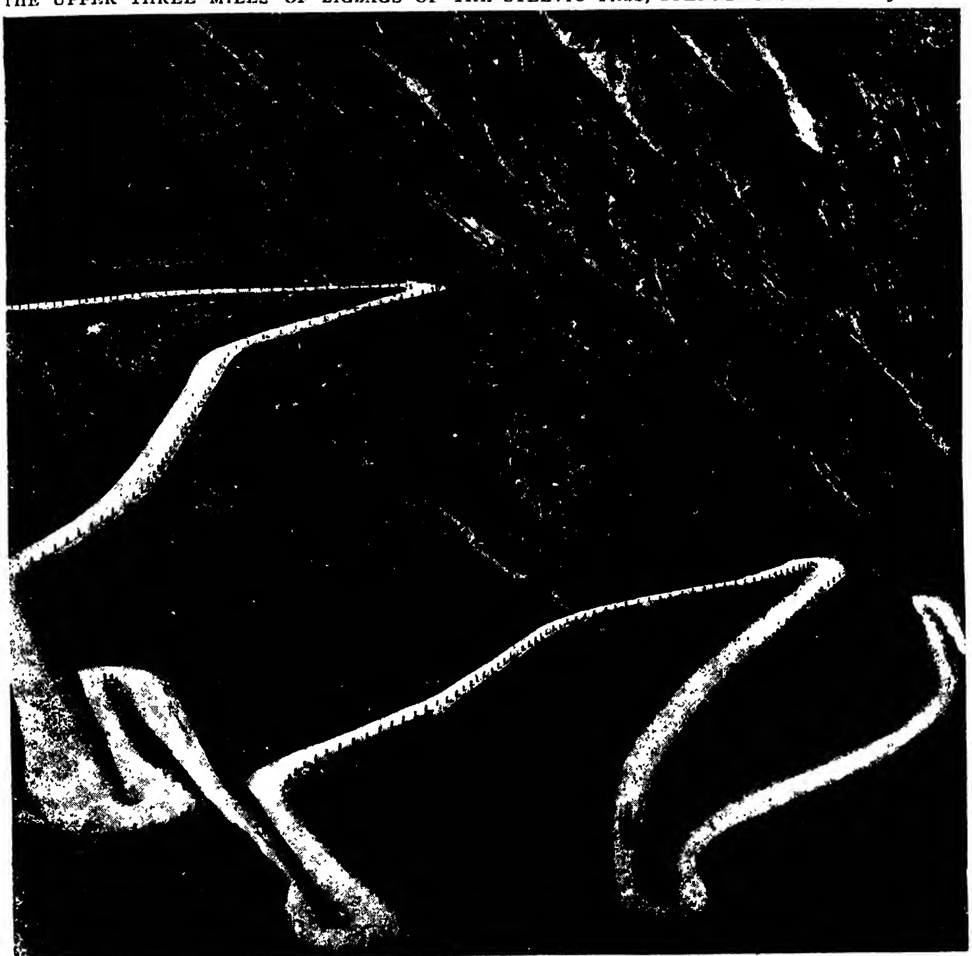
THE STELVIO PASS—THE ONLY MAIN ROAD IN EUROPE REACHING A HEIGHT OF 9000 FEET



THE AUSTRIAN SLOPE OF THE STELVIO BEGINS ABOUT 16 MILES FROM THE SUMMIT, AND THE UPPER SEVEN MILES ARE HERE SHOWN, AS SEEN FROM THE FOOTHILLS OF THE ICECLAD ORTLER SPITZ

THE GREAT AUSTRIAN HIGHWAY TO ITALY

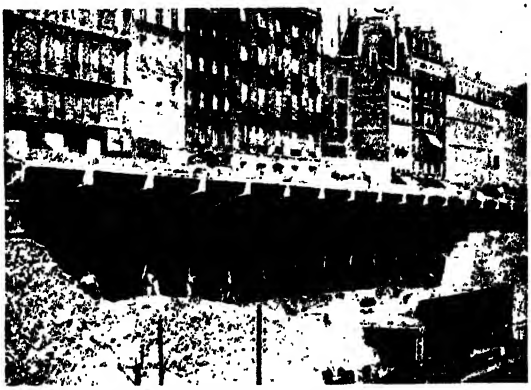
THE UPPER THREE MILES OF ZIGZAGS OF THE STELVIO PASS, OPENED YEARLY BY JULY 1



THE STEEPEST SECTION OF THE STELVIO'S CLIMB, AS SEEN FROM ABOVE

The photographs on this and the opposite page are reproduced by permission from "The High-Roads of the Alps," by C. L. Freeston; others are by the Photochrome Company, Underwood & Underwood, and Hills & Saunders

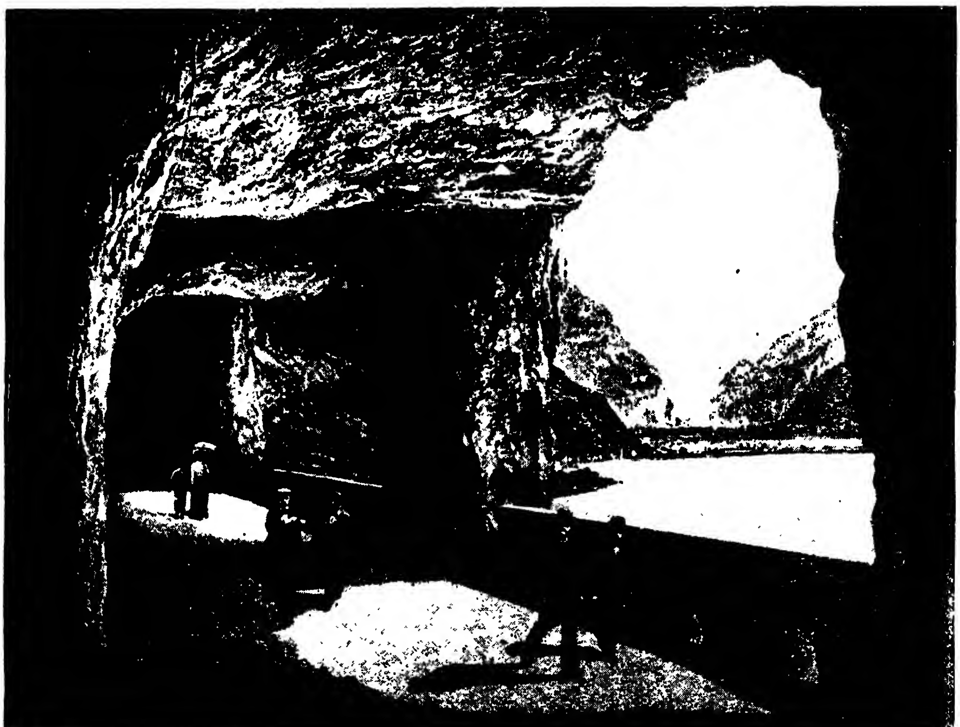
Joch, between the valleys of the Adige and the Adda, or Tyrol and Italy, was made by the Austrians as a means of retaining their hold on Venetia. It now costs two thousand pounds annually to reopen in summer this pass, which crosses the snow-line at a height of over 9000 feet. The repairs to such a road, of course, are incessant, and its full service is confined to about three months in the year. From the summit, looking down to Trafoi and the Tyroi, past the noble icy spire of the Ortler Spitz, rising sheer from the opposite side of the valley up which the winding road slowly creeps, seven miles of the zig-zagging ascent can be seen. The descent on the Italian side below the summit is much less precipitous, though lower there is repeated tunnelling to avoid the dangers of avalanches.



RUE DE ROME, PARIS, BUILT ON CONCRETE BRACKETS, TO ADMIT OF RAILWAY WIDENING

Another great Alpine carriage-road that is highly characteristic is the Splügen Pass on the Italian side, where, by a series of galleries, tunnelling in and out of the rocks, an almost perpendicular face of cliff is descended. Among mule-track passes the most noted probably is the Gemmi, between Kandersteg and the Rhône Valley, but the descent into Italy is so steep that mule-riding is forbidden, though the width of the road is five feet in its narrowest parts.

The aim of engineers in planning a road is to keep it to a gradient of about one in thirty, with a similar cross-gradient, on either side, for drainage purposes. On such a gradient a horse with a moderate load can trot either up or down, but, of course, in mountain districts that slope often must be exceeded; and in many towns short-distance gradients are found as



A CUTTING IN THE SOLID ROCK IN THE AXENSTRASSE

ON THE PEKIN PASS, THE HIGHWAY FROM MANCHURIA TO KOREA

steep as one in eight or ten. In the case of the Stelvio Pass the rise from the valley of the Adige to the summit of the pass is over 6000 feet, up a continuous ascent of a little over sixteen miles, or about one in fourteen, averaged throughout the whole upward journey. The usual gradient in the mountains of India is about one in eighteen. Mule-roads are sometimes engineered as steeply as one in four. A gradient of at least one in 120 is advisable on any road to give horses ease from the strain of working long on a dead level.

India can claim the most noted highway in the world, the Grand Trunk road. Starting from near Calcutta, it runs to Peshawar, where it joins the historical caravan track of the water-worn Khyber—one of Nature's roads. The magnificent Grand Trunk, a military road, gives sardonic evidence of the greater readiness with which man has made roads to facilitate war than to assist industry.

THE WHEAT SUPPLIES OF THE WORLD AND THE UNITED KINGDOM, WITH PRICES FOR FIFTEEN YEARS—1895 TO 1910

THE WHEAT FIGURES ARE IN MILLIONS OF CWTS., AND ROUNDLY TO THE NEAREST MILLION

	1895	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
UNITED KINGDOM CROP	20	31	30	40	36	29	29	31	26	20	32	32	30	29	34	30
FOREIGN IMPORTS:																
From Argentina	11	5	1	4	12	19	8	5	14	22	24	19	22	32	20	15
,, Russia	23	17	15	6	3	4	3	7	17	24	24	15	11	5	18	29
,, United States	45	53	54	62	60	58	67	65	47	18	14	36	33	41	25	18
,, Roumania	2	5	1	—	—	1	1	2	3	1	2	4	3	2	—	1
Total for above and other Foreign Countries	90	91	81	77	78	87	82	83	85	72	71	78	74	84	68	66
COLONIAL IMPORTS:																
From Australia	4	—	—	—	3	3	6	4	—	11	11	9	9	6	10	14
,, Canada	5	6	7	8	9	8	9	12	14	9	8	14	15	17	19	20
,, India	9	2	1	9	8	—	3	9	17	25	23	13	18	3	15	18
,, New Zealand	—	—	—	—	1	1	1	—	—	—	—	—	—	—	1	1
Total Colonial	18	8	8	17	21	12	19	25	31	45	42	36	42	26	45	53
Total Imports	108	99	89	94	99	99	101	108	117	118	114	113	116	109	113	119
United Kingdom Total Supply ..	128	130	119	134	135	128	130	139	143	138	146	145	146	138	147	149
The World's Wheat Production ..	1,220	1,190	1,140	1,460	1,310	1,330	1,390	1,590	1,620	1,460	1,600	1,660	1,510	1,590	1,890	1,730
United Kingdom Wheat Production, as percentage of entire British Supply	15·6	23·8	25·2	29·8	26·6	22·7	22·3	22·3	18·2	14·5	21·9	22·0	20·4	21·0	23·1	20·1
Price of British Wheat per quarter ..	23s.	26s.	30s.	34s.	26s.	27s.	27s.	28s.	27s.	28s.	30s.	28s.	31s.	32s.	37s.	32s.

FEEDING THE MULTITUDE

Our Increased Dependence for One Half of Our Foodstuffs Upon Foreign Commerce

WILL FOOD BECOME CHEAPER OR DEARER?

The feeding of the forty-five millions of men, women, and children who inhabit the United Kingdom in 1912 presents features of extraordinary interest, because British work is so largely concerned with other than agricultural pursuits. Time was when in every land the production of food was the primary pursuit of its people. The tilling of the soil was the staple occupation; industries were purely subsidiary. Commerce carried on with scientific instruments of transport has made it possible for the United Kingdom, and for several other nations in some degree, to base civilised life upon industry rather than upon agriculture. In the United Kingdom agriculture still occupies more people than any other single trade—about 2,000,000 men, women, and children—but this number is but about one-tenth of the total number of British men, women, and children engaged in occupations for gain.

There are two reasons why the British people can exist, and find sufficient food, while only one-tenth or thereabouts of their active workers are engaged in agricultural labour. The first is that the march of machinery and invention has made it possible to produce much more food with a given amount of labour than in days of old. This fact largely accounts for the movement of modern populations to the towns. The amount of food we can eat is strictly limited. If, therefore, science makes it possible to sow and reap with less labour, the proportion of people in any population needed to produce food must decline. That is what is occurring in practice in every nation, save where agriculture pursues primitive methods. As soon as science touches farming, the proportion of agricultural labour in a country must fall. This is a social fact of the first importance, the bearing of which is as yet scarcely realised.

Those who ignore it are only too prone to attach too much importance to schemes for getting workers "back to the land." If all men, or even a large proportion of men, returned to the land, there would be too much food produced, and labour would run to waste. The diminution of agricultural labour is inevitable, and it is not really a bad thing that it is so, for other labour need not be unhealthy, and man does not live by bread alone. The truth is that, the less labour needed for any particular kind of work, the more labour is set free to do other work; and as the desires of men are unlimited, and the possibilities of honest labour therefore unlimited, it is a good thing and not a bad thing that agricultural work is an ever-diminishing factor in the world in proportion to the aggregate amount of work done.

What we have stated as the main cause of rural depopulation is amply confirmed by the interesting report on the decline in Agricultural Population in the United Kingdom, published in 1906 by the Board of Agriculture. This report was based upon a most careful sifting of local reports from well-qualified correspondents. The report gave full weight to the elimination of agricultural labour in Britain through the laying down of land to grass, and went on to say: "There is little doubt that the saving of labour on the 15½ million acres which in 1901 still remained under the plough was in the aggregate greater during the twenty years (1881–1901) than on the two million acres laid down to grass. Many expedients, other than actually stopping the plough, were adopted to reduce the labour bill. But while manual labour has been economised to some extent by curtailing some of the operations which require it, the main cause of its reduction is the extended use of labour-saving machinery.

"This is referred to by the large majority of correspondents in all parts of the country. With the exception of the self-binding harvester, which was introduced into this country in the early 'eighties, few machines for the performance of a specific manual operation have perhaps been invented since 1881 (unless milking-machines, shearing-machines, and, perhaps, potato-diggers come within that category); but whereas twenty years ago labour-saving machinery was fully employed by comparatively few, it has now become almost universal on all holdings of sufficient size to make its use practicable."

Labour-Saving Machinery the Chief Cause of the Displacement of Manual Labour

"The substitution of mechanical or horse or hand power for fixed machinery—*e.g.*, thrashing-machines, chaff-cutters, pumps, etc.—has taken place largely, although it has made, comparatively speaking, little progress for tractive purposes. It may, indeed, be questioned if steam is so largely employed in the cultivation of the land as it was twenty years ago. But the displacement of manual labour arising from the greatly extended use of drills, horse-hoes, mowers, binders, manure-distributors, and the like must have been, in the aggregate, very great; and probably to this more than to any other single cause the reduced demand for farm labourers may be attributed."

It may be added that agricultural machinery was brought into use in British agriculture long before the date (1881) referred to in the report. The beginning of the nineteenth century saw steam employed in agricultural operations; and in 1855, at the great International Exhibition at Paris, mechanical reapers were exhibited.

How Four Men Working One Year Can Produce Wheat For a Thousand Men

The opening up of great areas of virgin soil in the New World gave a mighty impetus to the invention and use of labour-saving appliances; and at the beginning of the twentieth century one man employed in farming can easily do the work which needed twenty men in the eighteenth century. In this direction the engineer has helped to produce a social revolution by making industrial life not only possible but an absolute necessity for great sections of humanity. Increasingly it is becoming impossible for any but a small proportion of the peoples of modern civilisations to be agricultural labourers.

It has been estimated by an American economist, Mr. E. Atkinson, that under the conditions of modern farming on the grand scale, as in Dakota or Manitoba, the work of one man exerted for three hundred days is sufficient to produce wheat enough to feed 1000 people for a year: that the labour of another man for one year will carry the wheat to mill, turn it into flour, and put it into barrels, including the labour necessary to the making of the barrel; that the labour of two more men for a year is sufficient to move the product from the Far West to New York, to keep in repair and to maintain the farm, the machinery, and the railroad; "so that the modern miracle is that 1000 barrels of flour, the annual ration of 1000 people, can be placed in the city of New York, from a point 1700 to 2000 miles distant, with the exertion of the human labour equivalent to that of only four men, working one year in producing, milling, and moving the wheat."

We need not be surprised, then, that although we have only about two million agricultural workers (including men, women, and children), their labour is sufficient to produce a large proportion of the food needed by the British people. The common idea that we import by far the larger part of our food from abroad is a misconception of the facts, but it is becoming increasingly nearer the truth, as we shall see.

The Proportion of Its Food Produced by the United Kingdom at Home—One Half

By virtue of commerce we win much of our food from oversea, instead of growing it ourselves; and this is the second reason referred to why only one-tenth of our workers are engaged in farming. Nevertheless, it is not true that nearly all our food is imported, as is so generally believed.

If we turn to the records of our commerce in 1911, we find that our food imports were of the following value:

IMPORTS OF FOOD IN 1911

Grain and flour	£75,800,000
Meat	49,700,000
Other food and drink:	
Non-dutiable	73,600,000
Dutiable	59,900,000
	£259,000,000

It is an enormous importation. We have about nine million families in the United Kingdom, so that last year our food imports were worth nearly £29 for each British family, or over 10s. per week per family. Of the £259,000,000, however, the following items refer to products which we cannot conveniently produce in our latitude

FOODS WE CANNOT PRODUCE AT HOME

Maize	£10,700,000
Maizemeal	200,000
Rice and ricemeal	2,500,000
Other farinaceous products (say)	1,000,000
Fruits, exotic	6,500,000
Oils, exotic	2,500,000
Spices	800,000
Cocoa	3,200,000
Coffee	2,500,000
Dried fruits	3,000,000
Sugar	20,800,000
Molasses, etc.	2,700,000
Tea	13,100,000
Spirits	1,500,000
Wine	4,200,000
Other articles	1,000,000
	£82,200,000

So that in 1911 our importations of food of kinds we can produce ourselves was worth £259,000,000 less £82,000,000, or £177,000,000.

As we showed in Chapter 10, the value of British agricultural production in 1895 was estimated as follows:

VALUE OF BRITISH AGRICULTURAL PRODUCTION IN 1895

Crops	£63,600,000
Meat	74,300,000
Horses and other live stock	6,500,000
Dairy produce, eggs, wool, etc.	49,400,000
	£193,800,000

In 1911 our agricultural production was worth more than in 1895, owing to the rise in prices. To neglect that, however, and taking into account that horses, wool, etc., are included in the above figures, we see that the United Kingdom probably produces about as much food as it imports *of the kinds it is able to produce.*

If, therefore, we imagine the whole of the food of the British people produced in the United Kingdom, agricultural employment would obviously not find work for more than, say, another 2,000,000 workers, or about 4,000,000 workers in all. That would mean, say, 10,000,000 men, women, and children, including relatives, dependent on agriculture, *leaving 35,000,000 of our people to be necessarily dependent upon industry, even if we imported no food of a kind we could produce in our climate.*

The common impression that the greater part of our food comes from abroad has doubtless arisen from the fact that we do actually import the greater part of our wheat supplies.

Three-fourths to four-fifths of our daily bread comes from places oversea, and is earned by the exportation of British manufactures. The sources of our imported wheat form an interesting study. They are shown for a period of half a generation in the important table on page 2434. This period is of very great interest, because during it prices, not only of wheat but of most commodities, have risen throughout the world. The year with which the record opens (1895) saw British wheat at only 23s. a quarter, the lowest yearly average which has been recorded. Since that year, it will be seen, a great change has occurred. The price of 37s. was reached in 1909, and in 1910 the figure was 32s., or 9s. above 1895. The quartern loaf, which was at an average of 5d. in 1895, rose to 6d. by 1910.

The ordinary consumer rarely thinks of the interchanges and combinations which lead to the presence of the daily loaf in the baker's shop. Our table shows how varied are the constituents of that loaf. In one year we are largely renewed out of corn from India and the United States; in another year the familiar loaf is chiefly a combination of corn from Russia and Argentina. The record shown in our table is like the score of a cricket eleven. The runs are made, but not always by the same batsmen. The good corn arrives in England, and finds its way to our tables by processes to which we are largely indifferent, but its sources vary greatly from year to year. In 1898 two-thirds of our imported wheat came from the United States, a negligible quantity from Russia, a small amount from Canada and Argentina. In 1910 only about one-eighteenth came from the United States, while Russia supplied about one-fifth, and Argentina and Canada more than another one-fifth between them.

The change in the position as between Imperial and foreign supplies is very striking.

WHEAT FROM FOREIGN COUNTRIES AND BRITISH POSSESSIONS

	From Foreign Countries	From British Possessions
	Cwt	Cwt
1895	90,000,000	18,000,000
1897	81,000,000	8,000,000
1899	78,000,000	21,000,000
1901	82,000,000	19,000,000
1903	85,000,000	32,000,000
1905	71,000,000	43,000,000
1907	74,000,000	42,000,000
1909	68,000,000	45,000,000
1910	66,000,000	53,000,000

When the figures are closely examined, it is found that it is the decline of the United States as a food-exporting country which chiefly accounts for the change in the proportions. As the United States has fallen off, British Colonies, together with South America, have come to the rescue, and Russia has responded to the stimulus of higher prices.

In spite of the fact that the British farmer in 1908–10 was getting from 9s. to 14s. a quarter more for his wheat than in 1895, the British wheat area has not increased.

BRITISH ACRES UNDER WHEAT

1893..	1,900,000
1895..	1,400,000
1897..	1,900,000
1899..	2,000,000
1901..	1,700,000
1903..	1,600,000
1905..	1,800,000
1907..	1,600,000
1909..	1,800,000
1910..	1,800,000

We are seen to be for practical purposes as dependent on oversea wheat as when British wheat fetched only 23s. a quarter. It is a curious economic fact that, in spite of our large dependence on imported bread, we know nothing of famine; while countries which are almost entirely agricultural, such as Russia or India, are never free from the fear of famine. The reason will be plain from consideration of the table on page 2434.

A nation which is chiefly industrial, like the United Kingdom, and has a fine oversea commerce, has power in any year to draw upon all the harvests of the world. In any given year some harvests are seen to be available, although others may fail. Therefore, while we have power to export manufactures to pay for it, we can in any year depend upon getting the bread we need. The agricultural community, on the other hand, is chiefly dependent upon itself. Its only export can be agricultural products; and in a bad year, therefore, it has neither food of its own nor the means to pay for imported food. Thus it comes about that the agricultural country may at any time be visited by the terrors of famine, when the country which has to buy much of its food is safe. Safe, that is, as long as its shores and its trade routes are protected and secure. Without such security, the economic position of the United Kingdom would be not merely unstable; it would be unthinkable and untenable.

When we turn from bread to meat, we find the position very different. Whereas the British farmer supplies only a small proportion of the wheat we need, he supplies about one-half our meat. To form a true estimation of the respective proportions of our home and oversea supplies of meat is obviously a very much more difficult matter than to estimate the case as to corn. Fortunately, we have available the exceedingly valuable work which has been done by Mr. R. H. Hooker for the Board of Agriculture, and which he elaborated and examined in a paper read to the Royal Statistical Society in 1909. His estimates of the meat supply of the United Kingdom related to the years 1890–91 to 1907–08, and are sufficiently recent to give us a true idea of the trend of commerce in meat, and of the degree of our dependence on foreign and Colonial supplies respectively.

The importation of enormous quantities of meat is a feature of British trade which was not, of course, possible until scientific means of preservation were devised. British imports of meat did not rise above 10,000,000 cwt. until the 'eighties of the nineteenth century, but in the 'nineties they rose to over 20,000,000 cwt. This greatly increased importation, it is of deep interest to observe, has not reduced the British production of meat. The latter has also increased. Indeed, the consumption of meat in the United Kingdom increased more rapidly than the population until within the last few years, when it has been checked by the general rise in prices.

On page 2439 we give the results of Mr. Hooker's most important calculations. They exhibit our increasing dependence on external commerce for the second most important item in our national food supplies.

As to beef, the position has not varied greatly. In 1890–1 the home supply was 63 per cent. of the whole; in 1907–8 it was 61 per cent. Nevertheless, examination of the column shows a distinct tendency to increased dependence on imported beef; it is a tendency only too likely to increase. As to mutton and lamb, the change is remarkable. In 1890–92, 75 per cent. of the supply was home grown; in 1907–8, the home supply was only 56 per cent. of the whole. There was also a considerable change in the position as to pig-meat. In 1890–1, the home supply was 58 per cent.; in 1907–8 it had fallen to 43 per cent. of the whole. Taking meat of all kinds, the home supply in 1890–91 was 64 per cent. of the whole, whereas seventeen years later it had fallen to 54 per cent.

We saw that in the case of wheat the United States had of late years failed us as

BRITISH MEAT SUPPLY, SHOWING OUR INCREASING DEPENDENCE ON EXTERNAL COMMERCE

Year	BEEF AND VEAL				MUTTON AND LAMB			
	Home	Imported	Total	Per Cent. of Home to Total	Home	Imported	Total	Per Cent. of Home to Total
	mill. cwt.	mill. cwt.	mill. cwt.		mill. cwt.	mill. cwt.	mill. cwt.	
1890–1 ..	10·6	6·3	16·9	63	5·5	1·9	7·4	75
1891–2 ..	12·8	6·4	19·2	67	6·5	1·8	8·3	78
1892–3 ..	14·9	5·7	20·6	72	7·1	2·0	9·1	78
1893–4 ..	15·1	5·3	20·4	74	6·7	2·1	8·8	76
1894–5 ..	13·0	5·6	18·7	70	5·9	3·1	8·9	66
1895–6 ..	12·2	6·5	18·7	65	5·4	3·7	9·0	59
1896–7 ..	12·8	7·1	19·9	64	6·1	3·3	9·5	65
1897–8 ..	12·5	7·8	20·3	61	5·8	3·8	9·6	60
1898–9 ..	12·4	7·2	19·6	63	6·0	3·8	9·8	61
1899–00 ..	13·2	7·9	21·0	62	6·6	3·8	10·4	63
1900–1 ..	13·4	8·3	21·7	62	6·2	3·9	10·1	62
1901–2 ..	13·9	8·0	21·9	63	6·4	3·7	10·1	63
1902–3 ..	13·3	7·2	20·5	65	6·1	4·1	10·2	60
1903–4 ..	12·8	8·7	21·4	60	6·3	4·0	10·1	61
1904–5 ..	13·4	8·8	22·2	60	5·9	3·9	9·9	60
1905–6 ..	13·8	9·8	23·6	58	5·9	4·0	9·9	60
1906–7 ..	14·3	9·3	23·6	60	5·7	4·5	10·2	56
1907–8 ..	13·9	8·9	22·8	61	5·6	4·5	10·1	56

Year	PORK, HAM, AND BACON				TOTAL MEAT			
	Home	Imported	Total	Per Cent. of Home to Total	Home	Imported*	Total	Per Cent. of Home to Total
	mill. cwt.	mill. cwt.	mill. cwt.		mill. cwt.	mill. cwt.	mill cwt.	
1890–1 ..	6·5	5·3	11·8	55	22·6	13·0	35·6	64
1891–2 ..	7·5	5·0	12·5	60	26·8	12·9	39·7	67
1892–3 ..	4·8	4·9	9·7	49	26·8	12·3	39·1	68
1893–4 ..	4·2	5·0	9·2	46	26·0	12·5	38·4	68
1894–5 ..	5·1	5·5	10·6	48	24·0	14·2	38·2	63
1895–6 ..	6·2	5·9	12·1	51	23·7	16·1	39·8	60
1896–7 ..	6·8	7·0	13·8	49	25·7	17·3	43·0	60
1897–8 ..	5·3	7·9	13·3	40	23·6	19·6	43·2	55
1898–9 ..	5·3	8·6	13·8	38	23·7	19·4	43·1	55
1899–1900	6·3	8·5	14·8	42	26·1	20·3	46·3	56
1900–1 ..	5·6	8·5	14·1	40	25·2	20·9	46·1	55
1901–2 ..	4·8	8·4	13·3	36	25·2	20·5	45·7	55
1902–3 ..	5·0	7·0	12·0	42	24·4	18·7	43·2	57
1903–4 ..	5·9	7·4	13·3	45	24·9	20·6	45·5	55
1904–5 ..	6·5	7·5	14·0	46	25·8	20·8	46·6	55
1905–6 ..	5·2	7·5	12·7	41	24·9	21·8	46·7	53
1906–7 ..	4·8	7·2	12·0	40	24·8	21·4	46·2	54
1907–8 ..	5·8	7·7	13·5	43	25·3	21.5	46·8	54

* Includes "Meat Unenumerated" and less exports of dead meat (British and foreign)

a supplier. The same is true of meat, as will be gathered from the facts given in the following table.

BRITISH IMPORTS OF MEAT FROM U.S.A.
In Thousands of Cwts.

Year	Beef	Mutton	Pig-Meat	Total, including other Meats
1880 ..	2,138	36	5,281	7,980
1890 ..	5,187	7	4,234	9,499
1900 ..	5,693	83	5,925	11,971
1901 ..	6,397	173	6,462	13,330
1902 ..	4,970	105	4,954	10,404
1903 ..	5,149	140	4,057	9,646
1904 ..	5,487	165	4,145	9,935
1905 ..	5,415	90	3,986	9,795
1906 ..	5,397	49	4,011	9,716
1907 ..	4,890	52	3,256	8,443
1908 ..	3,361	42	3,645	7,283

As to the changes since 1908, although we have not an estimate of the same sort available, we are able to affirm that the American supply has contracted still further, and at an even more rapid rate than is shown above. Simultaneouly, the imports from Canada, Argentina, Uruguay, and Australasia have expanded, or it would have gone hard with the British consumer.

What are the prospects for the future? It will have been gathered that the last twenty years have been a time of great change in the sources of our food supplies. On the whole, they have tended to come more largely from the great British Dominions and South America, in compensation for a falling off in the once enormous United States export surplus.

In so far as the change is in the direction of an increased Imperial supply, it is undoubtedly a change for the good. We have seen that the British Isles, which already have to earn one-half of their food supplies from oversea, are becoming increasingly dependent on imports. That is a position which is stable only as long as we can maintain an impregnable position on the seas. Can the United Kingdom maintain naval supremacy? It is a question which goes beyond the province of this treatise, but it is our duty to accentuate its peculiar importance to the British people, who occupy an economic position which is unique. Can forty-five million people in the United Kingdom bear such an increase of taxation as shall in the future, as now, secure the sea highways by which alone they can feed themselves by commerce?

In this connection, the change to which we have referred—the larger proportion of oversea supplies of food which is coming from the British Dominions—is of no small moment. Obviously, supplies which come to us from the Colonies can only come by the high seas in common with foreign supplies, but a consideration of great importance arises in this connection which should not be overlooked. Looking to the future of the British Empire, it cannot be doubted that British naval supremacy can only be sustained if the burden is taken up by the oversea Britains as well as by the British taxpayer. The citizen at the heart of the Empire cannot for ever provide the necessary sea defences of our far-flung coasts, and of some 400,000,000 of people and their heirs. The citizens of Greater Britain are beginning to realise the fact; and surely their increasing commerce with the Mother Country will help them to realise it fully. It will soon become a matter of near moment to the British Dominions that the argosies which take their surplus food to the home country should be secure on the oceans. If we examine again the figures reviewed in a former chapter, we shall see how plain the lesson is. Here are the figures:

BRITISH FOOD IMPORTS FROM THE COLONIES

1906	£56,300,000
1907	61,700,000
1908	51,700,000
1909	63,800,000
1910	71,200,000
Increase	£14,900,000

Already the Colonies are concerned to see that £71,000,000 worth of food (plus, it may be added, £80,000,000 worth of materials) is secured in sea-transit to the United Kingdom in a year. The totals are growing rapidly, and will soon reach nine figures, both for food and for materials. These are facts which must tell heavily in forming Colonial opinion upon the naval position. If that position is realised in the Dominions no less than here, the British Empire and British trade are safe; if it is not, the position is one which a few short weeks of warfare might render irretrievably ruinous.

In considering the future of our food supplies, we find ourselves in considerable difficulty in attempting to appraise the many and varied factors of the case. In the period 1875–1895 corn was cheapened by the opening up of great areas of virgin soil in the New World. Great crops were to be had for very little labour, and prices fell rapidly until the latter date. The world

demand for wheat rapidly increased, but not so rapidly as rich lands were opened up. It was a process that could not proceed for ever. The point was reached at which the supply failed to expand as quickly as the demand, and prices rose again, as we have seen. There are still rich areas to be exploited in British North America, in Australia, in South America, and in some parts of Asia; but the number of wheat-eaters is rapidly growing, and the standard of life throughout the world is growing even more rapidly. It is not likely that the abnormal position of 1875–1895 will be restored. Cheapness, if it is to be regained, will be the work of the scientist in perfecting the processes of agriculture, in breeding more prolific wheats, in adding to our stores of artificial manure, in controlling climate, in stimulating plant growth, and in reducing labour.

In regard to meat, Mr. Hooker, of the Board of Agriculture, in the expert examination to which we have referred, feels compelled to regard the future of our imported supplies as "problematical." The United States surplus has sadly declined, and we shall have to look increasingly to the Southern hemisphere. It is not that the United States will have a decreasing *output* of meat, but a decreasing *surplus*; indeed, the time is not far distant when we may see her importing meat largely from Canada and from the Latin Americas. She may have 150,000,000 people by 1930, and to feed them will be a gigantic task.

In the great undeveloped areas of British North America, South America, Siberia, and South Africa there is room for large additions to the world flocks and herds. We have to note, however, not only that these lands will themselves grow greatly in population, but that others will compete with us for their produce. In Europe, Germany is making an ever-increasing call upon foreign food, and her population is growing at the rate of 800,000 a year. And not only Germany, but Europe as a whole, will find it necessary to call upon new lands to an ever-increasing extent.

AN ARTIST'S IMPRESSION OF THE EFFECT ON THE WHEATFIELDS OF THE EXPANSION OF CITIES

The economic relation of corn to mutton, and of mutton to other meats, is of much interest. The sheep is driven out when pasture is turned into arable. Arable does not drive out cattle as it does sheep, for when cattle grazing lands are ploughed the cattle can still be fed and developed side by side with the corn. That food supplies will eventually be plentiful and cheap there is little question, but it is exceedingly difficult to forecast the course of prices in the near future or for the next thirty years.

The probability is that the second decade of the twentieth century will witness considerable fluctuations in food prices around a point not lower than the level of those of 1911–12.

AN ARTIST'S ANTICIPATION OF THE ULTIMATE DOMINATION OF THE WORLD BY THE MACHINE

WHAT SOCIALISM LACKS

The Extraordinary Fluidity of Our New, Industrial, and Progressive Society

MEN BUILDING THE STATE OF THE FUTURE

It is a very remarkable fact that the present labour unrest of our country seems to have scarcely any political character. The struggle that is going on is an industrial struggle, in which the old weapons of the strike and the lock-out are used. In spite of the colour of French syndicalism that has been given to the fight for higher wages and better conditions of work, our working classes seem still to be individualists at heart.

In many cases their old leaders wished them to combine for a larger political action, with a view to obtaining control over the machinery of State. They pointed out that the workers of our country had within their reach four-fifths of the votes, and that an efficient system of political organisation would enable them to capture the engine of government and convert it into an instrument of Socialism. The success of the labour movement in the politics of some of our great Colonies went to show that the scheme was practical, but it apparently has not excited a general and formative interest among working people.

Indeed, the Socialistic party in Great Britain seems to be losing a good deal of its electoral power at the very moment when the discontentment of the labouring classes is fierce and active and widespread. For good or for evil a considerable number of workmen prefer to engage in a direct struggle with their employers, rather than organise themselves into a political party, aiming at the control of the State.

We have already noticed one of the reasons given for the revival of faith in the older method of the strike. Some of the new leaders of the trade unions hope to achieve more by industrial warfare than by Parliamentary action. The majority of the men, however, seem to have no long views on the matter. They are concerned in the individual and immediate side of the case; they want to better their organisation and their earning powers in order to recover the ground they have lost through the rise in the cost of living. If they can do this by means of strikes, or by means of the new machinery of arbitration for settling labour disputes, they will very likely lapse into a fairly quiet condition. How far the strike can be used to force up wages is a difficult problem, with which we hope to deal later. At present we wish to examine certain features of the Socialistic movement that has apparently for a time fallen partly into disfavour.

In spite of the fact that Socialism of the Constitutional sort has failed to appeal to our working classes in the present crisis in their affairs, it still attracts many earnest and thoughtful persons. Dazed by the waste of life and the suffering and disorder woefully patent in our industrial civilisation, they see in the nationalisation of all the resources of existence, and in the Government control of all industrial activities, the only permanent remedy for the poverty and drifting misery of our dark and troubled age. Socialism of some sort or another is coming to have almost the power of a religion over some fine and eager minds. Even in those castles of tradition the public schools and the universities, there is an astonishing amount of sympathetic interest in Socialistic ideas among the younger generation. So at least it is reported by observant head-masters and by university men.

In itself it is a good sign that the sons of the governing classes are being largely moved by sympathy with the troubles of the working people. A real quickening of the social conscience—the general social conscience—is the most vital necessity of modern civilisation. One of the chief

disasters of the industrial revolution is the gulf that it has made between the classes of our country. In the old days we happily escaped from class divisions by abolishing many of the feudal privileges that brought upon the French nobleman of the eighteenth century the scornful hatred of the French peasant. We were fairly well consolidated by fairly equal laws and by friendly relations between high and low. Our men in places of wealth and power shouldered the somewhat dull and routine work of administering justice, and of carrying out the details of local administration. For the most part they did their duties without any reward; and, in both their private and their official capacity, they were kept constantly in touch with the people.

But many a modern shareholder of means resembles a French nobleman of the old régime. He knows personally nothing about the workmen who help to earn the dividends on which he lives. All that he knows is that when they strike for higher wages they are striking for a reduction in his income. He often knows no more about the manner in which the income on his capital is obtained than he does about the manner in which the animal from which his meat is sliced was bred and slaughtered.

The Need for a Re-establishment of Human Relationships Between Employers and Emp'oyed

What, therefore, is needed is a large, quick, and general sympathy between the multitude of small anonymous capitalists, who are only sleeping partners in the manifold industries that they supply with funds, and the vast army of unknown workers who, ranged under foremen and managers, have lost all sense of human relationship with the shareholding class for which they are really labouring. In so far as the spread of Socialistic ideas among the younger generation of well-to-do people serves to stir the imagination and touch the feelings of the shareholders of the future, the gospel of Socialism prepares the way for industrial reforms.

In a larger manner it is also working upon the national mind and creating a mood favourable to social reforms on a wide scale. The orthodox Socialists are educating both of our old political parties, in much the same way as Lassalle, the German revolutionary of genius, educated Bismarck. Though Bismarck abhorred the principles of Lassalle's philosophy, he was quick to recognise the social value of some of the new ideas of industrial organisation; and when he was in a position to put these ideas int[o] practice he created a great scheme [of] industrial organisation which has taken ou[r] statesmen very many years to copy an[d] attempt to improve upon.

The Ingenuity of the German Workman in America though He is Sterilised at Home

But one curious effect of Bismarck's essay in Imperialistic Socialism has seldom been discussed. In Germany the work of invention that is building up new industries is almost entirely carried on by men of science, drawn from the well-to-do classes educated in universities. They practically form a caste, corresponding with the military caste, the manufacturing caste, the merchant caste, and the labouring caste. The power of initiative is no more wanted in a workman than it is in a private soldier. When, however, the German workman emigrates to the United States, he can compete with the best American minds in the genius for invention.

Since Mergenthaler constructed his first linotype machine in 1884, the emigrant German artisan seems to have done more than any other recent addition to the mingling races in the States to revive the faculty for mechanical inventions that once distinguished the American nation from all others. Being often a mechanic, without any scientific training, he does not strike out those large ideas that revolutionise the industrial world, but he produces improvements and rearrangements of well-known mechanical devices which facilitate and cheapen the everyday work of the civilised world. Just recently, for example, he has produced a new typewriter that does the work of a ledger clerk with extraordinary precision and rapidity. Taken singly, his achievements may not seem great, but they help the American manufacturer of machinery to keep up the creation of slight but ingenious and useful novelties in the use of mechanical power, by means of which he is still capturing new markets over all the earth.

The Lack of Originality Under Bureaucratic Governments

The fact is that too rigid a regimentation of the social and industrial activities of a race naturally impedes the general inventive genius. Even when a bureaucratic Government is sufficiently enlightened to allow scope for scientific enterprise, officialism stays the free and large progress of human powers. Already the spread of a mild kind of municipal Socialism has had a damaging effect upon some new and highly important

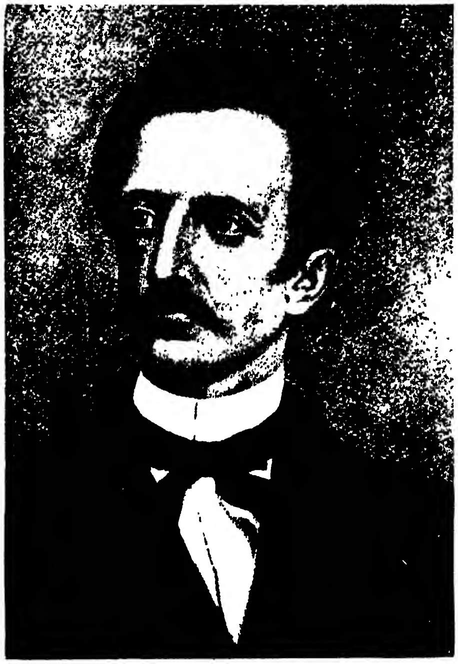
.lustrial activities of our nation, such as ·ectrical engineering, owing to restrictions ·laced on private enterprise,• however .atural and reasonable these restrictions nay be from another standpoint.

Full of enthusiasm for the future munici-alisation of large electrical enterprises, ur Parliament laid heavy penalties upon he persons who wished to run electric rams in our country, and an Electric .ighting Act was passed which had the nmediate effect of crushing all enterprise n regard to the supply of electricity. For, n order to advance the municipal control f the new force in industry, promoters of lectric supply undertakings were allowed nly twenty-one years' nterest in their pro-erty. The result was hat no capitalist vould provide money or undertakings with o short a tenure. It vas not until the assing of a new Act, n which the period f twenty-one years, fter which the under-aker was subject to urchase without any llowance for good-vill, was extended to orty-two years, that ur problems of elec-ric supply were ttacked by many of ur inventive minds, acked by funds by nterprising cap-talists.

But, in the mean-ime, American en-gineers and tramway ompanies, having een able freely to ompete with each other for the full rewards f invention, had obtained the lead in many ranches of electrical science. So at the ose of the nineteenth century the British ublic had to witness the humiliating pectacle of their municipal authorities ·ing forced to import from the other side f the Atlantic the electrical apparatus and ven the steam-engines specially used for amway purposes.

Behind any kind of Socialistic organisa-on there is always an official, and an ficial is a man who does not take risks. He waits to see if a thing is a great success sewhere before he advises its adoption. An enterprising capitalist, on the other hand, is able to take up a dozen new ideas and put them to the test; for one brilliant success will more than pay for all the failures. It has been well said that the true friend of inventive progress is the rising competitor in a busy hive of industry, where the difficulties of securing a profitable footing are very considerable.

Such a man is ever on the watch for an opportunity to gain some leverage by which he can raise himself to a level with richer and more powerful rivals. If he is a good employer, his workmen enter into the spirit of the competition, feeling that promotion may follow on any services they may render. They may even possess themselves some talent for invention, or they may do greater service by recognising the flame of genius in others, and co-operating in their work. It is thus that successful inventions are usually started on their useful careers.



FERDINAND LASSALLE

The advocates of Socialism often point to what has been done in the nationalisation of the postal services in our country, and of the railways in certain Continental lands. The State did not invent the telegraph and the telephone and the locomotive. It has merely engrossed the hard-won achievements of inventors and of enterprising men of means who backed the inventors at a time when the public was often inclined to ridicule and impede the working out of the new ideas. If the first inventor had gone to some Government or municipal official with a proposal to spend many thousands of pounds in testing and developing his new instrument of power, he would have been politely dismissed. But when, after years of intellectual labour and costly experiment, the outlay of perhaps millions of pounds of private treasure has created some large new force in civilisation, the official mind is ready, and even eager, to take over the accomplished success. Then very often it uses the monopoly which it

has seized as a weapon of unprogressiveness to keep all private competitors from the field of enterprise in which they could, in free and open battle, win their way again to the front.

What Socialism would appear to lack is progressiveness. It can organise, but it cannot create. It cannot even produce a social organisation with the scope and the stimulus for creative minds which are necessary for the development of the full powers of the human race. In order to change the world for the better, there must be left room and opportunity and means for carrying out the changes. Especially is this the case in regard to the development of fresh and larger powers of control over natural resources. What are needed are new ways of doing old things, and new ways of doing new things. These advances are not to be obtained by any system of official control over industrial activities that prevents men with creative minds from breaking their way through all traditions and privileges and social arrangements. Competition is here the grand force of progress. It may often involve in ruin the persons who show a want of enterprise, but on the ruin of their fortunes a new group of more inventive and more adventurous men rise into wealth and power.

The Faculty of Adaptiveness the True Protection for an Industrial Nation

Many years ago our shipbuilding industry was threatened with destruction owing to the invention of the American clipper ship. An extraordinary number of British shipbuilders went into bankruptcy, and the merchant marine of the United States looked like becoming the most important in the world. It was largely due to the internal disorders of the United States during the war over slavery that our country recovered the sea trade she had lost. Sudden and violent industrial revolutions of this sort will become more frequent in the next hundred years. Traditional skill and admirable organisation will not avail a people if their faculty of adaptiveness, their alertness of intelligence, and their genius for invention are inferior to those of other leading races. Many things will go down as the human race fights its way to the civilisation of the future. Probably wealth will change hands many times; large vested interests and even practical monopolies will be created by one inventor and destroyed by another.

Already our nation is getting into a kind of fluid state. Three hundred years ago men lived and died in the station to which they were born; trades and industries and crafts were handed down from father to son. In an artificial way, human society somewhat resembled those insect communities in which occupation rules every feature of the individual's life. Everything was settled and stable, quiet and orderly; there was not much progress, and yet there continued sufficient routine activities to prevent stagnation.

The Effects of the Stress of Inventive Changes on the Working Classes

Now it is a wise father who can choose a sure trade for his son. The bricklayer, with thousands of years of traditional skill behind him, may soon find that a great deal of his work is being taken away from him by a new kind of carpenter who makes moulds in which concrete buildings are poured. And the ordinary carpenter may, in turn, discover that a considerable part of his work is done by automatic machinery in some vast factory on the skirts of a forest. That workman succeeds best nowadays who is both highly skilled with his hands and quick and capable with his mind. Some of our engineering mechanics are excellent examples of the modern workmen of the best sort. They seize the principle of a new machine—of perhaps foreign invention—and construct it with an unrivalled soundness.

They are keenly interested in new ideas; and though they often complain that it is not worth their while to suggest improvements to a foreman of the shop, because he will take all the credit for it away from them, they are the picked corps of our great industrial army.

The fact is, they have been exposed to the full stress of inventive changes. Continually compelled to alter the details of the things they make, and sometimes to change the entire structure, they have been educated by an incessant struggle into the handiest and also the surest craftsmen that ever existed.

Coming Inventive Changes and Their Promotion of Social Fluidity

And what they have gone through, the workers in many other fields of industry will, sooner or later, have also to endure. If we may trust in certain reports issued by agricultural societies in America, even the modern ploughman will have to take up the study of high explosives, for ploughing by dynamite, it is reported, often adds 30 per cent. to the fertility of the soil.

A good sound general education that opens and exercises the mind, united with

a steady and yet enterprising temper of character, is becoming of more use to men of every degree than the knowledge and training that their fathers could hand on to them. Our industrial society is in a condition of fluidity, and this fluidity will not lessen but increase. Life is, in fact, becoming more of an adventure. This is owing almost entirely to the originating adventuresomeness of the inventor.

Capital, solid, well invested, and steadily fruitful capital, is scarcely in a better position than shifting, unquiet, hazardous labour. Great as may be its powers of organisation, it cannot organise itself against the inventor. It must wait on him and follow him. Marconi can do what all the Prime Ministers of our Empire could not of themselves have accomplished. He can bring the wealthy cable companies, representing millions of capital, to reduce their rates that once seemed firmly and highly established on a practical monopoly. In the same way there needs only the invention of a really cheap and strong motor-waggon to make our suffering farmers independent of railways in the cheap and rapid distribution of farm produce. And if the Brennan monorail soon becomes practical, our means of land transport will be swiftly and entirely revolutionised. Even coal-mining is not beyond the reach of the Samson-like grip of the modern inventor. He is already trying on a small scale abroad to turn a coal-mine into a vast gas-retort, and use the gas directly in generating electrical power.

With affairs in this extraordinary stage of transition, it is impossible to solve our present social problem by any of the methods advocated by Socialists. The entire reorganisation of human society is at present impracticable, for the reason that man has not yet built the foundations on which society can be permanently reorganised. The level of human power, the level of human character, the level of human virtue, is not yet high enough.

State control and State direction of all the conflicting energies and interests of a great, adventurous, free people cannot be established and maintained except by a mighty bureaucracy. A Socialistic bureaucracy must needs be efficient; without strong, capable, and knowledgeable men in large numbers to oversee the subordinate officials, the machinery of control would fall to pieces. Practically the man of the same class that now actively directs the industrial activities of the nation would win his way to power, but there would be little or no check on him. Having no competitors to fear, he would play for safety, and lose his qualities of enterprise; and seeing how easily human nature is corrupted by the exercise of despotic power, he would very likely grow more tyrannical in temper. No doubt he would usually act with the best intentions, but this would not make happier the lot of the men whom he was driving by public allowance against their inclinations.


MR. H. G. WELLS, SOCIAL THEORIST

Our postal service at the present time is mined by a fever of discontent, owing partly to the fact that many men in the lower ranks are angry with the personal ways of the Mandarins. And the present writer is informed that the Indian Medical Service has become a deplorable example of bureaucratic tyranny. The younger men are actually discouraged from pursuing lines of scientific research which might—and sometimes do—result in advances of importance in medical science. Their seniors sneer at them and hinder them, because they think the younger men are trying, by their studies, to win promotion out of their proper turn.

Practical Socialism of the administrative sort seems lately to have attracted some of the best of our minds. The common idea seems to be to collect an aristocracy of talent, composed of men of science, engineers, inventors, and give them the administrative control of the nations of the world. Or rather it is assumed that all the best men of this stamp will combine and fight their way to supreme power, and then reorganise our civilisation—a very bold and adventurous assumption.

The great French writer Ernest Renan seems to have been the first to think out this plan, which he developed from an idea of his friend Marcellin Berthelot, the master-chemist of the nineteenth century. Mr. H. G. Wells brought the scheme before the British public in a series of papers on "Mankind in the Making," which attracted an uncommon amount of attention. The idea appealed to many men of the younger generation in Conservative, Liberal, and Socialistic circles. It was one of the influences that created the New Liberalism that is now weakening the Labour Party by the simple but very effectual method of engineering large social reforms. It is also one of the influences which are reviving in the Conservative Party a desire to take part in some of the schemes of social betterment.

The older form of Socialism that was simply based on the notion of the conflict of Capital and Labour is practically obsolete. The interests of both the rich man and the poor worker have been subordinated to the idea of a bureaucracy of talent drawn from all classes, and entrusted with the task of promoting the welfare of humanity as a whole. Undoubtedly the new scheme of reorganisation of human society is larger and more practical than the working-class revolution of which the older Socialists dreamt. But, naturally, it does not appeal to the working people with anything of the force that the cruder scheme possessed.

In our view, human nature cannot be run into moulds, however fine. It is a plant which grows, and it grows strongest where it grows freely. No doubt there is existing in the world at the present day a scattered body of fine spirits in various walks of life. As they have grown up in an age of liberty, struggle, and incitement, it is probable that they are, on the whole, more enlightened, more capable, and more numerous than were the reforming minds in any other period of human history. So long as free institutions obtain, so long will this body of fine spirits continue to grow in number, in virtue, and in power. The very difficulties of their present condition are a source of inspiration. There is no need for them to construct in haste some system of material organisation that would give them the control of their fellow-creatures and afterwards impede the free development of genius of their successors. They are already united in an ideal communion. Though, for the most part, they dwell in loneliness, far away from each other, their minds breathe the same spiritual air, and, soaring above their earthly surroundings, assemble and converse in the same ethereal altitudes. On the free and continual exercise of the genius of these natural leaders of mankind depends the progress of the world. Make them officials, and you rob them of their creative qualities. Leave them but scope, opportunity, and freedom, and they will save the world in perhaps less than two hundred years. In the meantime, labour and capital will probably arrive at a working compromise by some of the means we shall venture to discuss in our next chapter, undeterred by the accident that the question is now in the state sometimes described as "burning"

THE CROWNING OF PITTSBURG
From the fresco by Mr. Alexander in the Carnegie Institute, Pittsburg, photographed by the Detroit Publishing Co.

AMERICAN DISCOVERIES

Illuminating Studies of Heredity in Feeble-Mindedness Published by Investigators Working on Mendel's Lines

THE PROPAGATION OF DEGENERACY

Having discussed in outline the features and the projects of the Eugenics Record Office in the United States of America, we now turn to the first three bulletins already issued by that office, in order that as we proceed we may have behind us the knowledge which the American Eugenists have lately contributed to the study of human heredity. That knowledge deals in the main with morbid conditions of body or mind, and therefore will especially concern us at a later stage, when we come to study the problems of Negative Eugenics, or the control of unworthy parenthood; but it includes the establishment of a sound method which is necessary for all the objects of eugenics, and which cannot too soon be described and followed on this side of the Atlantic.

Taking the three bulletins in the most convenient order, we may begin with the first to be issued, which is entitled "Heredity of Feeble-Mindedness," and comes from the pen of Dr. H. H. Goddard, superintendent of the training school for defective children at Vineland, in New Jersey. This paper is a revelation: and the sooner the knowledge it contains reaches the textbooks, and supersedes their speculation and vagueness on this subject, the better for everybody.

The scientific evidence laid before our own recent Royal Commission on the Care and Control of the Feeble-Minded belongs to the realm of mere likelihood or personal conjecture when compared with the detailed, wide, and exact inquiry we owe to Dr. Goddard and his helpers. It will later be seen that, while the evidence of Dr. Goddard confirms the long-standing demand for proper care of the feeble-minded, it will soon require us to modify that demand, along lines which are indicated by none of the existing proposals, if we are to make no unnecessary regulations and to include all that are necessary. We shall here discuss this invaluable bulletin, which places our knowledge on a new level, in some considerable detail, because the reader may find it difficult to obtain a copy of the original paper.

The American workers found that, as we have all always known, the answers of parents to the formal questions regarding the ancestry of children for whose admission application was being made "were not sufficiently accurate to be valuable." Often the parents say what they think most likely to ensure the child's admission; and in any case sufficient information has not hitherto been demanded for any really effective inquiry into the heredity of mental defectiveness. Therefore the authorities at Vineland prepared a new form, or "After-Admission Blank," containing very careful, detailed questions about the relatives of the child. "This blank was sent to all parents and physicians, with a little note urging them for the sake of the child to tell all they possibly could about the child's relatives, their condition, any diseases they had had, any habits, such as alcoholism, any insanity or the like, which had occurred in the family. . . . Upon the basis of this information we prepared charts of the children, which were truly remarkable in what they revealed as to the etiology [causation] of feeble-mindedness. This spurred us on to more careful and detailed work. We were fortunate enough to find some philanthropic people who were glad to furnish the funds necessary to employ two field-workers. . . . The field-worker goes out as the superintendent's personal representative, with a letter from him recommending her and urging the parents, for the sake of the child, to tell all they possibly can, and to send her on to other

relatives or to anyone who may be able to give the information, which may be used to help their child or someone else's child. The response has been full, free, and hearty. Parents do all in their power to help us get the facts. There is very rarely anything like an attempt to conceal facts that they know. Of course, many of these parents are ignorant, often feeble-minded, and cannot tell all that we should like to know. Nevertheless, by adroit questioning and cross-reference, we have been able to get what we believe to be very accurate data in a very large percentage of our cases."

A Method of Inquiry that Finds Order Where Others Have Found Chaos

Later we shall have to study more closely the details of the method which is outlined in the foregoing, and which has already proved its superiority to all others, finding order and intelligibility where the methods of our biometricians, for instance, in the same field have found nothing but chaos and unreason. Meanwhile we must look at the kind of results which appear, when something like eighty family trees, thus constructed, are studied and compared. Needless to say, we no longer waste our time on anything that does not provide us with at least three consecutive generations; and it is necessary to be most particular in including normal as well as abnormal members of the stock in our reckoning, for we cannot possibly ascertain any Mendelian ratios in the transmission of feeble-mindedness unless we do so, and can compare the respective numbers of the affected and the unaffected. But this simple point is one which was never attended to before the present inquiry, and it is the non-observance of it that in a large measure accounts for the failure of all previous inquiries to show what this inquiry reveals.

The Terrible Rule of Heredity in Feeble-Mindedness

The facts of any given stock can be readily made graphic by constructing a family tree, and filling in the various individuals with black or white symbols, according as to whether they are feeble-minded or normal. And no sooner has this simple device been followed than the very first chart we construct shows us, what all the others in turn show us—that feeble-mindedness is something *definite*, like brownness or blueness of the eyes, which appears beyond dispute in one child, but not in another. Or, rather, that is what we find when the chart begins with a pair of grandparents, or ancestors remoter still, who were not both feeble-minded. *When two feeble-minded persons marry, they produce none but feeble-minded children.* No observer or recorder has yet furnished us, from any part of the world, with an exception to that rule, which means, as we now begin to see that where the feeble-minded factor comes in from both sides, it is bound to appear in the offspring.

That, of course, is a practical fact of the highest importance; but in itself, while it tells us much about the heredity of feeble-mindedness, it cannot tell us enough. It is when we study charts of stocks to which normal and feeble-minded persons have contributed that the parti-coloured look of the chart catches our eye. We should have expected that the mental condition of the defective ancestor would colour the whole stock, but we find nothing of the kind. On the contrary, the ancestral defect appears in full measure in some individuals, and not at all in others. No student of Mendelism could look at these charts of feeble-mindedness without saying at once "It segregates"; and the problem is for us to find out exactly how this segregation or separation of the morbid factor actually occurs, so that it goes into one child and not into another.

Some Results of Specific Inquiry Into Abnormal Inheritance

Such a possibility is of double interest, for it means the solution of a scientific problem, and it means the possibility of controlling feeble-mindedness, and removing it from a stock, just as the modern botanist can control this or that desirable or undesirable characteristic of wheat, and fix the one or remove the other.

A few typical charts from this bulletin may be briefly described. The whole of the details are unnecessary, for the work is not yet completed; and Professor Bateson, in his Herbert Spencer Lecture of the present year, has shown that more must be done before we can be certain as to the exact Mendelian description of feeble-mindedness. The first chart (page 2453, chart I.) shows how all the children and grandchildren of two feeble-minded persons were themselves affected, the children having married persons like themselves. Proceeding, we look at the feeble-minded husband from the second stock, and find that his father was a drunkard and his mother normal. Among his brothers and sisters were normality and feeble-mindedness, and the children of the normal members of the family were themselves all

normal. Thus, in this family, it looks as if the father's alcoholism had affected a proportion of his germ-cells, so that he had defective children who transmitted their defect, and normal children who transmitted their freedom from it.

Deeply Instructive Facts which Only Madness can Ignore

Dr. Goddard's analysis of the third chart may be quoted in his own words: "Chart III. is instructive, in that it seems to show the effect of a combination of alcoholism and mental defect in the father, when the mother's family is good, herself and sisters being normal. The result of this woman's marriage with a feeble-minded, alcoholic man is five feeble-minded children, five that died in infancy, two others that died before their mental condition could be determined, and one normal child. Apparently a clear case of transmission through the father." It is also a clear case of what should not happen in any decent and humane community.

The fifth chart is deeply instructive—one of the few at present existing which provide us with a sort of natural experiment, in the case of mankind, comparable to what we may so readily observe in plants and the lower animals. It is the case of an alcoholic man, from an extremely healthy family, who first married a normal woman. There were eleven children, of whom several died young, probably owing to the father's alcoholism, as Dr. Goddard suggests, but there was no feeble-mindedness. However, this man married a second wife, alcoholic and feeble-minded, whose two sisters, brother, father, and mother were alcoholic also. Of the seven children of this second marriage, five are to be reckoned feeble-minded, and the two last are as yet too young for us to be certain. The contrast between these two large families of the same father is most noteworthy.

An Example where Mental Defects Skip a Generation

In the next chart we have a marked instance of the defect "skipping a generation." The maternal grandmother was feeble-minded, but of her eleven children none were so. Yet of twelve grandchildren of hers of whom we have record, six were feeble-minded. This is a complicated chart, which it would take too long to describe further, but there is the salient fact. If this family had only been studied as regards the first two generations, everyone would have said that the assertions as to the heredity of feeble-mindedness were flatly contradicted by it, for here is a feeble-minded woman with eleven children, all free from the defect; yet, when we go a stage further, as Mendelian inquiry has proved that we always must in the study of heredity anywhere, we find that of twelve grandchildren half have the defect in full measure. It is the study of such charts as these—and their number may be added to by anyone who will take the trouble to record any trait for three generations—which shows us that the reports of our biometricians on parental alcoholism and tuberculosis, dealing only with two generations, are worthless for any purpose except that of a warning.

The next chart shows a normal father who was twice married. The first wife was feeble-minded, and bore him a child like herself, and a second that died in infancy. The second wife was normal, and bore him four normal children.

The Abominable Abuse of Parenthood which Society Allows

Then follow a couple of charts which both refer to the history of one man, an alcoholic, who proves to be the key to the records of five children now at Vineland, who were supposed, until this inquiry was made, to represent three independent families. This man came from a sound family, "but was spoiled in his bringing up, became alcoholic and immoral—a degenerate man. His first wife, however, was a normal woman, and it is claimed that the two children were normal. For his second wife he took out of the poorhouse a feeble-minded woman. Her children were two normal, one that died young, and one feeble-minded." His third wife had already had three illegitimate feeble-minded children, and after the marriage she had three more, all feeble-minded. The full study of the various stocks with which this man is connected, by these marriages and otherwise, shows clearly that society has sinned gravely in allowing him ever to marry at all, or to have the liberty he has so abominably abused; and it also shows that feeble-mindedness is a definite thing, with a definite basis in the germ-plasm, and that its further analysis will reduce it to the sway of the Mendelian law (charts II. and III., page 2453).

The next chart is of extraordinary interest, clearly foreshadowing complications in the study of human heredity and in the practice of eugenics, at which previous methods of inquiry have never hinted. An alcoholic man, with peculiar fingers, was married twice. The first wife was normal. There were nineteen children,

not one of whom inherited the father's peculiar defect in the number of joints in his fingers. Here, then, is a case where the evidence is nineteen times repeated that "there is nothing in heredity," for the father's "brachydactylism," as it is called, was not transmitted. But this man married, for his second wife, a feeble-minded and alcoholic woman, the daughter of two alcoholic parents; and hear the sequel. By this second wife there were eight children, every one of whom inherited the feeble-mindedness of their mother *and* the peculiarity of their father's fingers. Compare the two families of this man, and we learn that heredity depends not only upon the characteristics of the particular individuals concerned, but also upon the particular combination of individuals. The first wife was, in the language of heredity, prepotent as regards the peculiarity of the husband's fingers, and it could not appear in even one of nineteen children. The second wife was not prepotent in this respect, and all the eight children inherited their father's peculiarity; but she *was* prepotent as regards her mental condition, and transmitted it to all her unfortunate children, though their father was free from it.

The Presence of the Exception that Proves the Rule

We may here pass over various charts which illustrate what these observers have already shown that all the offspring of two feeble-minded parents are always feeble-minded; and that the defect skips a generation in many instances, so that, in order to control it, we should in certain cases have to forbid parenthood to individuals themselves normal, in whose germ-cells, nevertheless, the defect would remain, transmitted from a defective parent. But the twelfth chart published in Dr. Goddard's paper is of special importance, because it shows us a case of marked, hopeless, and characteristic mental defect, without a trace of any such thing being discoverable in any of twenty-six near relatives, including the parents and grandparents, all of whom were normal. What does this striking exception to all our other charts signify? Naturally, we look for alcoholism, as a possible originating cause of defect in a previously healthy stock—a racial poison, as the writer calls it. But there is no more record of vice or bad habits than of natural defect in this stock. Further inquiry shows that this is just the exception which proves the rule. The defective child in question is what is known as a "Mongolian idiot," because the appearance of the face and the form of the eyelids strongly suggest the characteristic physiognomy of the yellow races.

Wide survey of these cases shows that they are a type apart. They do not occur in association with feeble-minded stocks. The general rule is that these children are the last of large families, the members of which have succeeded one another at very short—too short—intervals. The mother's powers are exhausted by the recurrent strain; and at last she produces an unfortunate child with this curious facial appearance, a hopeless idiot, who is to be looked upon as a case of arrested development, the cause of arrest seeming to come into action at a very early stage of antenatal life.

Exceptions Traceable to Defective Nurture, not Nature

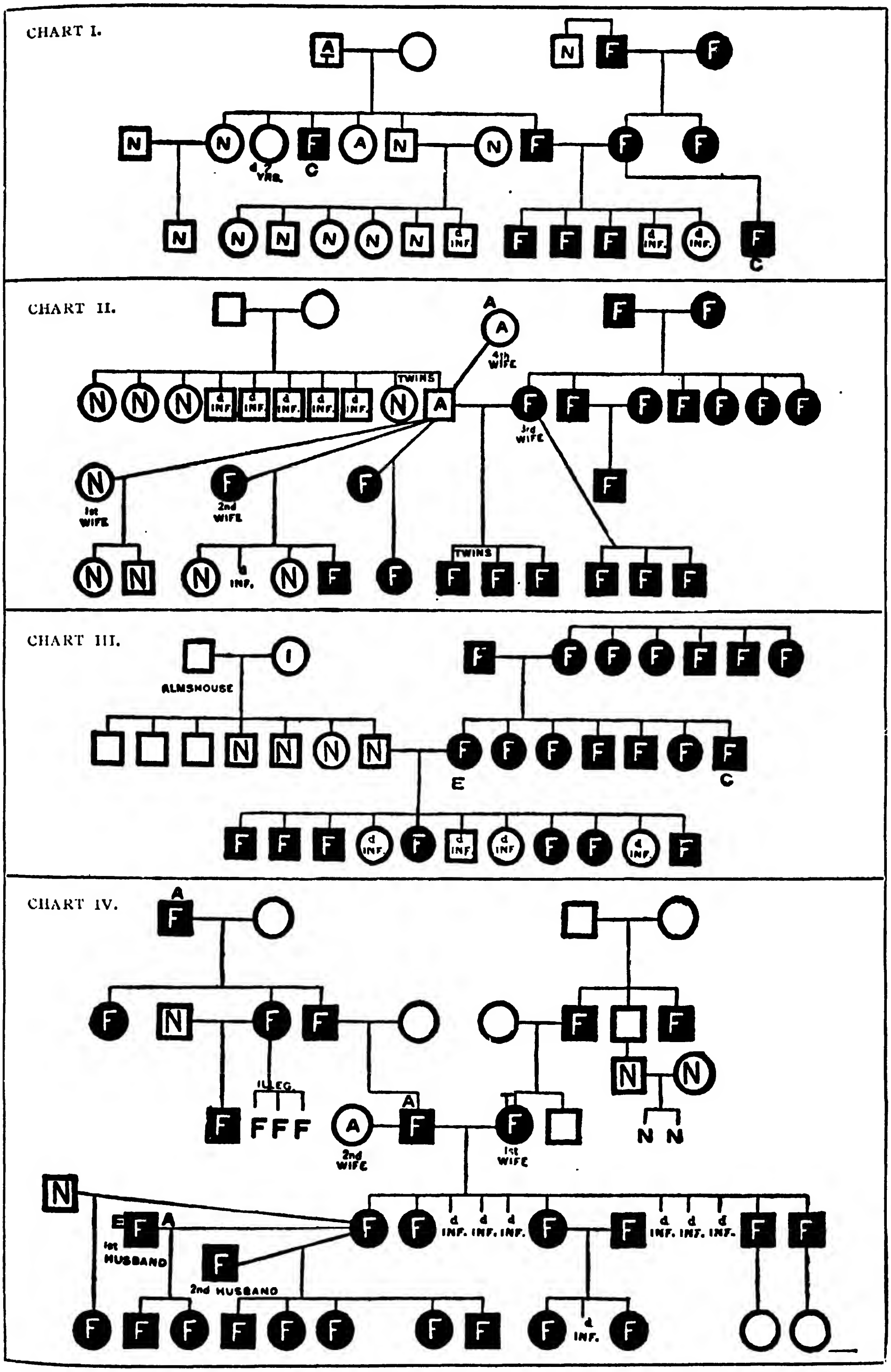
Obviously, it is of the highest importance for eugenics that this type of cases should be distinguished; and there may be others which belong to the same class, but which our methods have not yet sorted out. From the standpoint of science and of eugenic practice it is cardinal that we should be able to distinguish absolutely between two things so distinct as hereditary transmission of a defect and defective nutrition acting upon an individual whose heredity is healthy. This is just one more instance of the all-importance of distinguishing between "nature" and "nurture," which we are ever insisting upon here, but which many Eugenists are content to ignore.

Passing over charts which show the transmission of feeble-mindedness through four generations, we merely note in passing that these exact American pedigrees lend no support to the vague statements, only too familiar, that defects can be bred out in time by union with healthy stocks; that the tendency is to return to the standard of health, according to Galton's law of "regression towards mediocrity," and that we must not despair of any stock if only we give it fair conditions.

Untenableness of the Idea that a Bad Strain May be Bred Out by Breeding from It

The records show that all these assertions are meaningless. The transmissible forms of mental defect are due to germinal factors which are not looked upon by Nature as good or bad; are neither favoured nor frowned upon, but are simply transmitted in a regular and orderly way, which we have now all but ascertained, just like a host of other characteristics, normal and abnormal, valuable and deplorable. Certainly this

FAMILY TREES OF HUMAN DEGENERATES



A MENDELIAN STUDY OF THE EFFECTS OF LAWLESS PROPAGATION BY THE UNFIT

symbols used are as follow: Square indicates male, circle female; A, alcoholic; C, criminal; E, epileptic; F, feeble-minded, er black letter when sex is unknown or white letter on black ground; I. insane N. normal; T, tuberculous; d inf., died in infancy

clear demonstration of mental defect as due to definite germinal or genetic factors, like eye-colour or type of hair, is the most important fruit of the American investigation. We shall very soon find, in all probability, that certain types of mathematical and musical talent behave in just the same way, and then the irrelevance of statements about the good conquering the bad, "regression to mediocrity," and so forth, will be apparent.

A Family with More than a Hundred Feeble-Minded Members

The last chart (see chart IV., page 2453) presented by Dr. Goddard comprises a personal history so appalling that we can only outline it here, but it is too instructive to be ignored. The central figure is a feeble-minded woman, who has four feeble-minded brothers and sisters, the father having been feeble-minded and alcoholic. At the age of seventeen this wretched girl left home and got a situation as a domestic servant. Just so do large numbers of feeble-minded girls start life in this country every year, and at just about the same age —usually their sixteenth birthday or as soon as possible after it; and their subsequent history follows along the same lines as in this case. This woman has now had eight children, all feeble-minded, having been twice married and once divorced, under shameful circumstances. The family has been further investigated since Dr. Goddard prepared the chart he published, with the result that 119 of its members are found to be feeble-minded, and only 42 are known to be normal.

There is no need for us to assert more for this paper than what it evidently contains, and its palpable lessons have already been stated; but no student of heredity can look at it without wishing to go one stage further. Plainly, feeble-mindedness has a genetic basis, and is about to be elucidated on Mendelian lines.

The Analysis of the Causes of Feeble-Mindedness Waiting for Further Observation

It is most probably due to the absence of some factor or factors from the germ-cells, so that it belongs to the category of what the Mendelians call "recessives." But Professor Bateson says that he would "hesitate to describe feeble-mindedness as a simple Mendelian recessive," and we must wait until the analysis has been pushed probably just one stage further. Nevertheless, the work of the American school of Eugenists upon this subject has been beyond praise; and they have already given us enough for the purposes of wise, humane, and efficient legislation, which must be discussed when we come to the problems of Negative Eugenics.

We may now conveniently study in brief the third bulletin, issued in May, 1911, by Miss Cannon and Dr. Rosanoff, of New York, and entitled "Preliminary Report of a Study of Heredity in Insanity in the Light of the Mendelian Laws." Here we approach a much more difficult subject than feeble-mindedness, and one on which the bark of biometry has split, just because insanity exhibits, in far greater degree, the problem which the American students have illustrated, for feeble-mindedness, by the contrast between the pedigrees of Mongolian idiocy and those of the other forms of feeble-mindedness that they studied. It is the old question of nature and nurture again. Nay, more: the problem of nurture in the narrower sense is complicated here by that of infection with microbes, for there are several forms of insanity which are due to microbes or to animal parasites, and in these the hereditary factor is non-existent or negligible, while in other forms of insanity it is as important as in the majority of Dr. Goddard's pedigrees of feeble-mindedness.

The Need for the Study of Genetics by All Engaged in the Treatment of Insanity

Thus there is no department of human heredity, not even excepting genius, on which more copious and confident nonsense has been poured forth, by practically all students except those who alone are acquainted with the nature of the problem —namely, the mental physicians and first-hand students of mental disease. But these students, whom we nowadays usually call alienists, rarely have had an opportunity for study of heredity in general; and the bulletin now before us is actually the first record of a first-hand inquiry made by alienists who were also equipped with adequate knowledge of genetics. The problem before the authors is thus early and fairly stated by themselves—

"It has been shown that the laws governing the transmission of traits by heredity, as established by Mendel, hold good not only for plants and the lower animals, but also for man—at least, as regards certain characters, such as colour of hair and colour of eyes. In view of this fact, our problem has assumed for us a more definite form. It is simply: Are any of the forms of nervous and mental disease transmitted from generation to generation

in accordance with the Mendelian laws?" Our interest in this paper at the present time is chiefly dependent upon its method, and we must be brief in noting the authors' conclusions. First, they found, from their detailed study of pedigrees which comprised thirty-five different matings, that a great variety of symptoms, to which doctors give quite distinct names, really depend upon the same basis in the germ-plasm. This is what the most distinguished alienists have been suspecting for many decades. In one person the fundamental defect shows itself as mere eccentricity, in another as hysteria, in others as evident insanity of many types; but these differences, most of which have separate names as separate "diseases" in medical terminology, are shown to be really not diseases but *symptoms* of what is really the same flaw in all cases. From every point of view this is a most important conclusion; and the best comparison to bring this home to the reader is perhaps the discovery of the tubercle bacillus by Koch, enabling doctors to group together dozens or scores of different "diseases," of every part and function of the body, and to recognise them all as different *symptoms* or manifestations of one thing—tuberculosis.

The Hope of Tracing all Forms of the Neuropathic Taint to One Cause

Obviously, such a discovery is the essential step towards ultimate control of the disease, and undoubtedly the same may be claimed for the definite discovery that the "neuropathic taint," or "insane diathesis," is the real disease, which may show itself in as many different combinations of symptoms as there are patients. Once trace all these infinitely various symptoms—as various as the nervous systems of different individuals—down to a single, definite, transmissible, predictable cause, and our future control of the disease is assured.

The authors of this bulletin carefully avoid the mistake of the English biometricians, and separate general paralysis, which is due to a parasite, and alcoholic degeneration of the nerves, from the other conditions they study; and they also have clearly identified one or two minor nervous symptoms as genuine independent entities, due to a definite Mendelian factor. Such, for instance, is *one form*—by no means the commonest—of chorea, or St. Vitus's dance, technically known as Huntingdon's chorea. Having done so, they write a sentence which the reader must carefully compare with what we have already learnt regarding feeble-mindedness: "The pedigree charts contain a number of instances of neuropathic children born of normal parents, *but not a single instance of a normal child born of parents both of whom are neuropathic.*"

When the authors had completed their work they found that the correspondence between the pedigrees and a certain theoretical expectation was very close—too close for chance to account for. The theoretical expectation was based upon the assumption that the "insane or neuropathic diathesis" is of genetic origin; that it is due to the absence of a single Mendelian factor from the germ-cells, and that it is thus what the Mendelians call a "recessive." This enables us to predict the consequences of the various kinds of matings that may occur, just as we can predict the colour of sweet-peas.

The Bearing of Mendelian Laws on the Transmission of the Neuropathic Taint

Thus, "both parents being neuropathic, all children will be neuropathic; both parents being normal and of pure, normal ancestry, all children will be normal, and not capable of transmitting the neuropathic make-up to their progeny." In between these extremes there are four other possible types of matings, each with its Mendelian consequences, but here we need only quote one of them, in order to show what this discovery means for eugenics, and how utterly this American work supersedes all that has gone before it: "One parent being normal and of pure, normal ancestry, and the other parent being neuropathic, all children will be normal, but capable of transmitting the neuropathic make-up to their progeny." Here we observe how "skipping a generation," as it used to be called, comes in again, and how much worse than useless is all the English work which depends on the study of only two generations.

The Soundness of American Methods of Inquiry, and Need for Their Adoption Here

Here we need only state the fact that the second bulletin issued by the American Eugenics Record Office is entitled "The Study of Human Heredity: Methods of Collecting, Charting, and Analysing Data;" and its principal author is Professor C. B. Davenport. It is enough for us to avail ourselves of the words of this distinguished student, in comment upon the paper just described, and then we shall realise what an advance it stands for. At an important medical discussion in New York, Professor Davenport described the reasons why this

paper by Miss Cannon and Dr. Rosanoff supersedes all previous work; and we insist upon this, because we must follow the American method in this country unless more time and money are to be thrown after all that have already been wasted.

First, the American discovery depends upon the new method of collecting the data. "In their work, an attempt was made to employ the best scientific methods —*i.e.*, to find out what the exact facts were, at whatever cost of time and expense. A person biologically trained, and trained in the rapid diagnosis of mental disease, visits the family to which the patient belonged, and enters into such a cordial relation with the members of that family that the mother, for example, soon becomes quite willing to tell the truth, whereas, if she were brought before the hospital officials, she might hesitate or decline to tell the facts. In addition to this, the field-worker, who is not limited as to time and expense in her attempts to learn the facts, can visit other members and branches of the family; she can see the family physician and the neighbours in order to corroborate the statements made by the parents or wards. By this method, in the course of time, the field-worker obtained the real facts in the case; and such a history, when compared with that usually obtained in the hospital, clearly demonstrated the total inadequacy of the latter."

The Need for Particular and Not General Inquiry and Study in All Cases of Inheritance

It is these totally inadequate records which alone have been studied for the heredity of insanity everywhere hitherto; and it need hardly be said that the magnificent mathematical equipment of our own biometricians has been useless when applied to them. No less important is the second method, applied for the first time in this case. As Professor Davenport says:

"The second advance in the paper of Miss Cannon and Dr. Rosanoff relates to the method of studying the data they have collected. Hitherto, in studying the data of these cases, it had been considered impracticable to get the law of inheritance from a single family, and the practice had been to lump the data, and say, for example, that in one hundred cases of insanity a distinct inheritance was found in thirty-five. This method of lumping the data had not been generally satisfactory, and was of no practical use in predicting what would be the outcome of the children of a particular mating, nor was it of any particular value in explaining how a particular insane patient came to exist. The present method avoided this massing of the data by boldly attacking each family, and recognising that the insanity was due to a particular combination of maternal and paternal germ-plasms. This gave an entirely different value to the study of heredity, and enabled us to say that a particular mating would necessarily give rise to such and such a proportion of insane offspring, or that a certain insane patient must have had insanity in both the maternal and paternal germ-plasms."

The Importance of Environment Left Untouched by the Study of Heredity

Lastly, we must quote the following valuable comment by Dr. Rosanoff himself upon this remarkable paper, for which all Eugenists must always be grateful: "The results of heredity studies did not exclude factors of environment from the etiology of mental disease, but rather added evidence to show their importance. In the material which formed the basis of the paper, practical findings did not correspond exactly with theoretical expectation, and the excess over expectation was always on the side of normal offspring. It would seem that the neuropathic make-up was a character which presented shades of variation as numerous as those in the depth of brown-eye colour, hair-colour, etc. While in some instances the neuropathic make-up was so well marked as to be plainly manifest from birth, in others it consisted of nothing more than an undue lack of mental balance, which resulted in attacks of insanity consequent upon comparatively trivial causes, such as childbirth, a moderate indulgence in alcohol, or some psychical shock."

Neuropathic Taints Left Latent if Nurture is Favourable

We see from this admirable interpretation of an admirable piece of work that the factor of nurture still tells, and that in a proportion of individuals the neuropathic taint, while present in the due Mendelian way, is latent so long as the nurture is favourable, but when such people indulge or strain the organism an attack of insanity follows. Plainly, here is a lesson alike for Natural and for Nurtural Eugenics.

With this we must leave, for the present, the American school of Eugenists, who have taught us so much, by going properly over ground traversed without a key by hundreds before them, and who have placed that key in our hands for employment in all departments of eugenics.

SHADOWS IN THE HEAVENS

The Conditions of Eclipses of the Sun and Moon, and the Strategy of Observation

THE TERROR OF CELESTIAL CHANGE

An eclipse of the moon, and still more an eclipse of the sun, must always be a strange and awe-inspiring spectacle. The word "eclipse," meaning in Greek "fainting" or "failing," shows what the ancients felt as they watched the darkening of the heavenly lights; they saw them languish and swoon under some dreadfully ominous visitation. Eclipses, like comets, were taken to be portents of war, pestilence, the death of princes, or even of the end of the world; and to this day certain more primitive peoples come to the aid of the sun or moon with various rites and clamorous supplications.

Eclipses are caused by the shadows of the earth and of the moon. The earth and moon being opaque bodies, each of them always has a shadow extending outward into space away from the sun; and because both earth and moon are smaller than the sun, the shadow of each of them is conical, and diminishes in diameter as it proceeds outward into space, until it comes to a point. As the moon travels round the earth once in every month, she sometimes throws her shadow on a portion of the earth's surface, and sometimes herself enters into the earth's shadow. The former case, causing a solar eclipse, can only take place at new moon; the latter, causing a lunar eclipse, can only take place at full moon. There would, therefore, be an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon, if the moon's orbit round the earth were quite in the same plane as the earth's orbit round the sun.

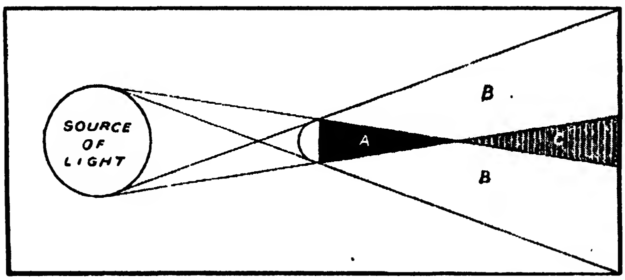
The moon's orbit, however, is not in the same plane as the earth's orbit, but is slightly inclined to it. The moon passes through the plane of the earth's orbit twice every month, being for half the month below that plane, and for half the month above it. Usually, therefore, the moon's shadow at new moon passes above or below the globe of the earth, and thus fails to eclipse the sun. Usually, also, at full moon, the moon passes above or below the earth's shadow, and so fails to eclipse herself. But from time to time the moon is at full moon or at new moon at the moment when she is at one of the points where her orbit crosses the plane of the earth's orbit; and when that happens, there is a lunar eclipse at full moon or a solar eclipse at new moon. The plane of the earth's orbit round the sun is called the "ecliptic," and the points in the orbit of the moon where she crosses the ecliptic are called the "nodes" of her orbit. Eclipses, whether of the sun or of the moon, take place when the moon is at or near the nodes of her orbit.

Let us now consider the different parts of the shadow which is thrown by the earth or the moon. They may be illustrated by a diagram which represents an opaque and non-luminous globe, illuminated by a larger and luminous globe. The diagram does not, of course, in the least represent the relative sizes or distances of the sun and earth, or of the sun and moon, but it shows well enough the various regions of complete and partial shadow which are actually projected into space by the earth and the moon. In the first place, there is the central region of complete shadow, marked A. An object situated within any part of this cone receives no light from any part of the luminous body; and an observer within this cone cannot, therefore, see the source of light at all.

Secondly, surrounding the cone of complete shadow, there is a region of partial shadow, marked B. This is known as the penumbra. Any object within it receives light from a portion of the luminous body; and an observer within it can see a portion

of the source of light. Thirdly, the lines, or rather the surface, bounding the conical region of complete shadow, if extended outward beyond the point of the cone, form an inverted cone, marked C, which is called the negative shadow. Any object within the negative shadow receives light from an external ring of the luminous globe; and an observer in any part of the negative shadow will see the source of light as a luminous ring round the opaque body which is interposed.

It is not difficult to calculate the length of the shadows of the earth and of the moon. It is evident from the diagram that the length of the cone of complete shadow depends upon three factors—the diameter of the source of light, the diameter of the opaque body, and the distance between these two bodies. These three factors are known with considerable accuracy, both in the case of the earth and in that of the moon. But while the diameters of the sun, earth, and moon are constant factors, the distance between sun and earth and between sun and moon are variable factors. Consequently, the shadow of the earth and the shadow of the moon vary in length. The length of the earth's shadow, at its longest, is about 871,000 miles; at its shortest, about 843,000 miles; and at its mean, about 857,000 miles. The length of the moon's shadow is about 236,000 miles at longest, about 228,000 miles at shortest, and its mean is about 232,000 miles.



THE DEGREES OF DARKNESS IN ECLIPSES

For a full explanation see text

The length of the earth's shadow being about 857,000 miles, and the average distance of the moon from the earth being only about 239,000 miles, it is obvious that when the moon plunges into the shadow of the earth she is much nearer to the base than to the tip of the conical shadow. The diameter of the cone, where the moon passes through it, varies from about twice the diameter of the moon to about three times that diameter. If the path of the moon happens to take her right through the centre of the shadow, she may remain totally eclipsed for about two hours. To this time must be added another hour from her first contact with the shadow until the moment of her total eclipse, and yet another hour during her emergence from the shadow, so that a lunar eclipse may last, from beginning to end, as long as four hours.

On the other hand, the total phase of the moon's eclipse may last only a few minutes if the path of the moon takes her near the edge of the shadow. If the moon's path is such that only a portion of her disc, and not the whole, enters into the conical shadow, the eclipse is partial and not total. Sometimes her path, escaping the cone of complete shadow, takes her through the penumbra of the earth, but under these circumstances she still receives so much light from a portion of the sun's disc that there is no marked obscuration of her surface unless she passes very close to the true shadow.

The moon is usually not altogether lost to sight even in the midst of her total eclipse, but shines with a strange, lurid, copper-coloured glow. Although the earth's globe, so much larger than the moon, is interposed directly between the sun and her, yet sunlight reaches her with sufficient illumination to show up the main features of her surface. This is sunlight which has been deflected by the earth's atmosphere. When we witness from the earth a total eclipse of the moon, observers on the moon would see a total eclipse of the sun, but they would see the great ball of the earth surrounded all round its edge by a glowing ring of sunlit atmosphere; and the rays which would thus reach their eyes constitute the light that illumines the moon during total eclipse. The terrestrial atmosphere acts as a lens, bending some of the sunlight which passes through it into the shadow of the earth. If, however, the earth's atmosphere be heavily charged with clouds, and is consequently comparatively opaque, it fails to deflect sunlight into the earth's shadow; and under those conditions the moon's surface may be so obscured as to be altogether invisible. The lurid, ruddy colour of this glow is due to the quality of the atmosphere to which we owe the gorgeous tints of sunset. The light which thus passes from the sun to the eclipsed moon has obviously had to traverse more than twice the distance through the atmo-

sphere which the rays of the setting sun have to traverse before they reach our eyes; and the tinting effect of the atmosphere, with which we are familiar in sunsets, is therefore more than doubled.

Eclipses of the moon are not quite so frequent as eclipses of the sun. There are years within which there is no eclipse of the moon; and in general it may be said that there cannot be more than two lunar eclipses in any one year. If, however, there is an eclipse of the moon on one of the first days of the year, it is possible that there may be a third eclipse in December. The statement that eclipses of the sun are somewhat more frequent than eclipses of the moon seems to be contrary to our experience, for everyone must have noticed that in the country where he lives eclipses of the moon are considerably more frequent than eclipses of the sun. These two facts are not really in contradiction with one another. The moon's shadow, as it reaches the earth, covers only a very small space, whereas the earth's shadow, as it reaches the moon, is more than twice the moon's diameter. Every eclipse of the moon is therefore visible to the inhabitants of more than one half the earth's surface, but the regions from which any particular eclipse of the sun can be seen lie in a very narrow track across the globe. Astronomers have to undertake expeditions to remote corners of the world to study eclipses of the sun, but eclipses of the moon can be seen at home. Yet, from the astronomical point of view, eclipses of the sun are incomparably more important, as well as more frequent. There are at least two solar eclipses every year, and there may be as many as five.

A SOLAR ECLIPSE VIEWED FROM SPACE

Inasmuch as eclipses both of the sun and of the moon depend upon the regular movements of these bodies, their occurrence, both in the future and in the past, can be calculated with great exactness. Thus we know from published tables that within the next ten years total eclipses of the sun will take place as follows: On October 10, 1912, visible in the northern parts of the South American continent. On August 21, 1914, visible in Scandinavia and in Russia. On February 3, 1916, visible from the West Indies and the islands of the Pacific. On June 8, 1918, visible in the United States of America. On May 29, 1919, visible in South America and in Central Africa. On September 21, 1922, visible in East Africa and in Australia. The list might be indefinitely extended for thousands of years to come.

The power, within certain limits, to foretell the occurrence of an eclipse appeared very early in the history of scientific knowledge. The Chaldæans were able and patient students of the heavens: we have, for instance, records of a total eclipse of the sun observed in Babylon as early as 1069 B.C.; and many centuries before our era every considerable city in the region of the Euphrates and Tigris had its observatory and official astronomers. Thence astronomical knowledge passed to Greece, where Thales of Miletus, the earliest of Greek philosophers, made a vast reputation by predicting an eclipse of the sun, which duly took place, on May 28, 585 B.C.

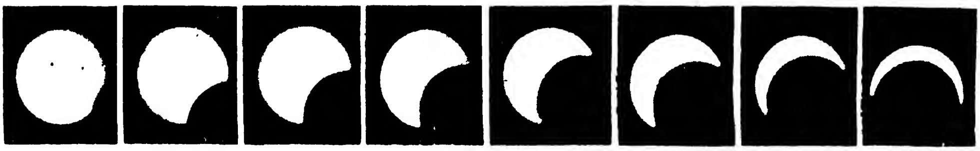
This early astronomical feat is, after all, not so surprising as it may appear, for patient observers who were careful to keep records of celestial events must soon have become aware of the periodic recurrence of eclipses of the sun and of the moon. Such is the regularity of the movements of the heavenly bodies that whatever eclipses take place in any particular year will be repeated after an interval of eighteen years eleven days and about eight hours, so that eclipses come round again at the right time with the precision of the hands of a clock. This period of recurrence is still known as the saros, a name meaning "repetition," applied to it by the ancient Chaldæans. In each saros there are about seventy eclipses, including about forty eclipses of the sun and about thirty of the moon.

It must be added, however, that although each eclipse of the sun or moon recurs after this period of eighteen years and eleven and one-third days, every such eclipse only has a certain limited life, the life of a solar eclipse being considerably longer than that of a lunar eclipse. Thus, an eclipse of the sun begins as a partial eclipse, in which the moon only slightly encroaches on the sun's disc. At the recurrence of the same event after the period of the saros, the moon obscures a larger area of the sun. Next time, the eclipse, though still partial, is again greater in extent; and this extension of the eclipse is repeated after every saros. These partial eclipses are followed ultimately by a series of annular and total eclipses, in which, from some place on the earth's surface, the moon is seen to pass across the centre of the sun's disc, either nearly covering it, as in an annular eclipse, or obscuring it altogether, as in a total eclipse. Finally, the eclipse dies out, as it arose, by a series of ever-diminishing partial eclipses. In this way the same eclipse returns at the interval of the saros, about seventy times, and it may be as often as seventy-five times, the whole process, from its first to its last appearance, covering nearly thirteen centuries. Any given eclipse of the moon increases and declines in the same way, but has a shorter life, recurring only forty-eight or forty-nine times, at intervals of eighteen years and one-third days; so that the whole life of a lunar eclipse, from its first to its last appearance, extends to less than nine centuries.

Eclipses of the sun are of three kinds—partial, annular, and total. An observer situated within the penumbra of the moon, marked B on the diagram, sees a partial eclipse; an observer situated within the negative shadow, marked C on the diagram, sees an annular eclipse; and an observer situated within the true shadow, marked A on the diagram, sees a total eclipse.

We have seen that the mean length of the moon's shadow is about 232,000 miles, and its greatest length is about 236,000 miles. The mean distance of the earth from the moon, is, however, 238,800 miles, so that in general the moon's conical shadow is not long enough to reach the earth. At times, however, the moon is within less than 218,000 miles of the earth's surface and her true shadow may then completely hide from the sun's rays a small area of the earth's surface, causing at that point a total eclipse of the sun over an area which cannot exceed 167 miles in diameter. At other times the moon may be nearly 249,000 miles away from the earth's surface; and if she is then interposed between the sun and the earth her negative shadow will partially obscure a small area of the earth's surface, causing at that point an annular eclipse of the sun. Around the area on the earth's surface where there is total eclipse or annular eclipse of the sun, there is always a very much larger area where there is partial eclipse. This area of partial eclipse, caused by the penumbra of the moon, extends for about two thousand miles over the earth's surface on each side of the path which is followed by the area of total eclipse.

The path over the earth's surface, which the area of total eclipse will traverse at any given eclipse of the sun, is carefully computed and mapped beforehand, so that astronomers may take up advantageous positions for observing the eclipse. The point of the moon's shadow passes along this track at a great speed, always considerably exceeding a thousand miles an hour; and the longest period for which totality can last at any one point, under the most favourable conditions, is just short of eight minutes.



A PARTIAL ECLIPSE OF THE SUN—A SERIES OF PHOTOGRAPHS TAKEN

The approach of a total eclipse of the sun is always described as impressive and even alarming. The clouds darken, the air becomes chill, and a murky gloom pervades the sky. Birds fly to shelter, and other animals show signs of alarm. The cold and darkness rapidly increase. Then the black shadow of the moon, like a vast thundercloud, advances with fearful rapidity from the western horizon, and covers the whole sky. Just before the last rays of the sun are obscured, swiftly moving bands of light and shade are seen to pursue one another over any white object on the ground, and are probably due to uneven refraction

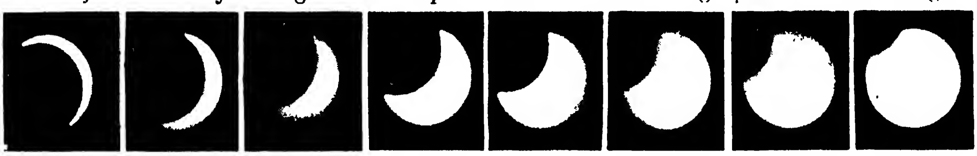
in the atmosphere. Then the day is like night. As the eyes become accustomed to the darkness, surrounding objects are seen in strange appearance, without their natural colours. Even an experienced beholder has the sense of some awful impending calamity. All Nature appears to be dead.

In the sky, as the eclipse approaches totality, the sun is seen as an excessively narrow crescent of brilliant light, round the eastern edge of the advancing moon. This crescent becomes a mere curved line, and then breaks up into irregular beads of light, known as Baily's beads, supposed to be due to the last glimpses of the disappearing edge of the sun's disc, between the mountains at the edge of the moon. These quickly disappear; totality is complete; and the moment has come for which astronomers have prepared for many months and travelled thousands of miles.

The chromosphere with its prominences, and the corona, which have been already described in Chapter 18, are among the chief objects of study during a total eclipse. But a modern eclipse expedition investigates these structures in several ways, and undertakes many other observations also, and is altogether a very elaborate undertaking, employing many hands and equipped with very elaborate and costly apparatus. Parties of this kind go out from each of the countries which are more advanced in scientific interests, and often two or three parties from one country; and in the case of the more accessible eclipses these more or less official expeditions are followed by many amateur astronomers. The track of the moon's shadow is dotted in advance with temporary observatories, occupied by eagerly expectant students.

One of the most important points to be determined during a total eclipse of the sun is the precise moment of each of the four contacts. These contacts are: The first, when the moon first encroaches on the sun's disc; the second, when the last rays of the white light of the photosphere are cut off, and the moon stands out like a round black ball against the corona; the third, when the first gleam of the white light of the sun reappears; and the fourth and last contact, when the moon passes completely off the sun's disc. These times of contact are observed both by the eye with the aid of a telescope, and by means of photography.

The chromosphere and prominences can now be studied, as we have seen, by means of the spectroscope at all times, so that they no longer take up quite so much attention during the brief and valuable moments of eclipse. Observations of the corona, on the other hand, are restricted to the period of totality. Notwithstanding the great advance of photography, ocular impressions of the corona are still indispensable. The observer is blindfolded for ten minutes before the moment of total eclipse, so that his eyes may be in the best condition to perceive the delicate, far-reaching streamers and filaments of light. For the same purpose opaque discs are erected on poles to cut off the brilliant light of the inner corona, so that observers in fixed positions behind them may be sensitive to its tenuous outer structures. Photographs of various lengths of exposure are taken of the corona, and its spectrum is recorded by means of the prismatic camera, in which separate images of the corona are formed, corresponding to each of its constituent elements.



12.11 p.m. | 12.21 p.m. | 12.31 p.m. | 12.41 p.m. | 12.51 p.m. | 1.1 p.m. | 1.11 p.m. | 1.21 p.m.

FROM A ROOF IN LONDON DURING THE ECLIPSE OF APRIL 17TH, 1912

The period of total eclipse is further utilised in searching for possible planets near the sun and within the orbit of Mercury. This search, formerly made by ocular observations with the telescope, is now made more rapidly and completely by means of photography.

The bolometer, an instrument of exquisite delicacy in the measurement of heat radiation, is used to determine the heating effect of the radiation of the corona, with a view to discovering whether the light of the corona is due to reflection of the sun's rays by particles of dust, or to the luminosity of these particles themselves, due to their incandescence from the heat of the sun. For this purpose the heat-rays are spread out, as in the spectroscope, to form what is known as an energy spectrum, and the energy spectrum of the corona is compared with that of the sun itself. If the coronal light

is reflected light, the energy spectrum of the corona will be similar to that of the sun, but if it is due to the incandescence of dust particles, the coronal energy spectrum should differ from that of the sun. Recent bolometric observations of the corona have led to the conclusion that its light is due principally neither to reflection nor to the incandescence of dust particles. The corona radiates too little heat to be quite consistent with either of those theories. It seems to be becoming more probable that the main light of the corona is due to a glow electric discharge, but further observations are necessary to determine the point.

Coronagraph mounted equatorially — The eclipse clock — Three-colour camera coronagraph

The dark-room — 6-inch prismatic camera — 16-foot coronagraph

THE OBSERVATION CAMP OF THE ECLIPSE EXPEDITION TO PALMA, MAJORCA, IN 1905

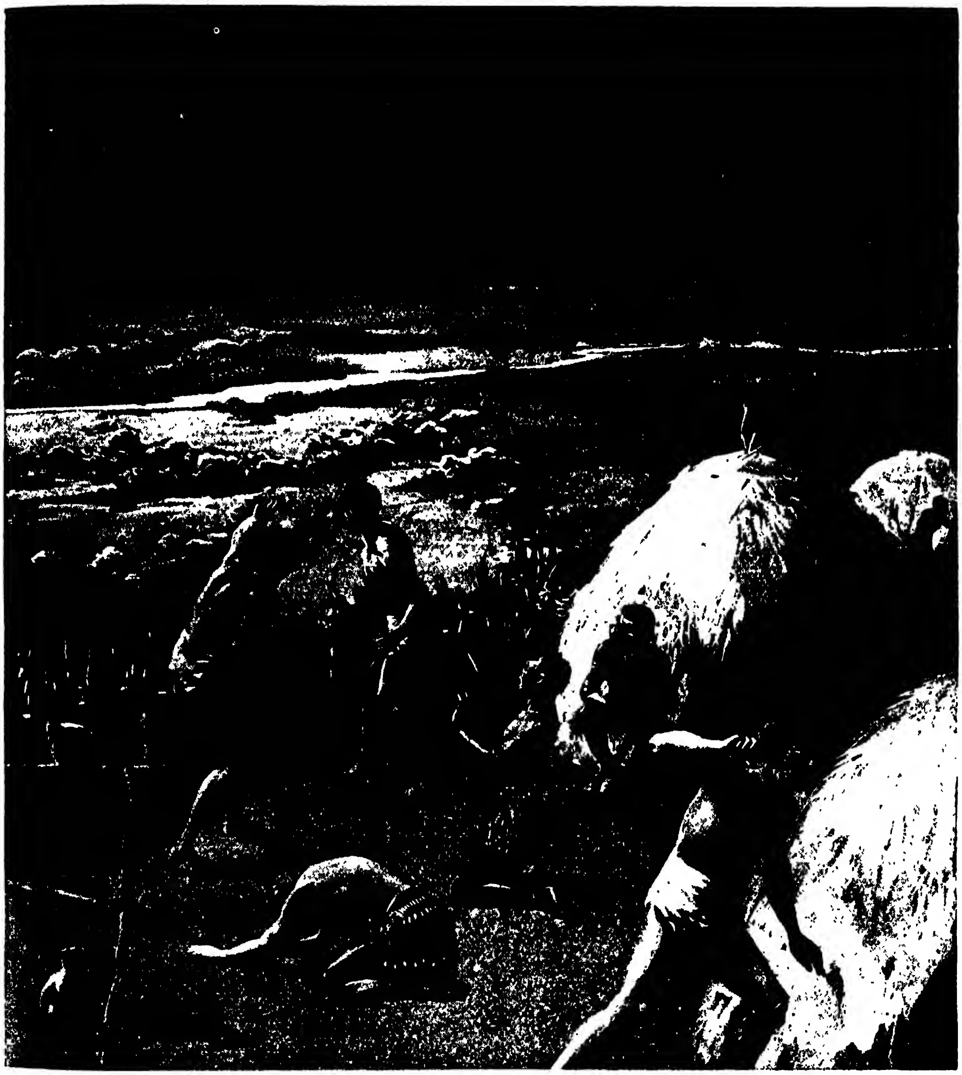
From photographs supplied by courtesy of Dr. W. J. S. Lockyer, of the Solar Physics Observatory, South Kensington

To obtain satisfactory results in all these different inquiries, and to waste no moment of the precious minutes of the totality, involve extraordinary care and foresight in preparation, organisation, and drill. Sir Norman Lockyer, most enthusiastic and capable of eclipse observers, has brought to perfection the art of conducting an eclipse campaign. On the occasion of the eclipse of 1896, which he observed from the extreme north of Lapland, the weather proved unkind, and no results were obtained from that station, but he succeeded in showing that the officers and crew of a British warship may be transformed, with a week's drill, into a very powerful engine of astronomical research. His force of volunteer observers was disposed as follows: To the 6-inch prismatic camera, five men; to the 9-inch prismatic camera, six men; to the integrating spectroscope, three men; to disc observations of the corona, six; to making sketches of the corona, sixteen; to observing the colours of the landscape, eight; to watching the advent of the moon's shadow, four; to the 6-inch equatorial with grating, six; to the $3\frac{3}{4}$-inch telescope, three; to the slit spectroscopes, four; to prisms for rings, two; as timekeepers, three; to determine the contacts, five; to the polariscope, two; to meteorological and thermometric observations, six; to the observation of stars, three; to the landscape camera, one; to observation of the shadow bands, one.

On the occasion of the 1898 eclipse in India, Sir Norman Lockyer was in command of one hundred and forty well-drilled and organised observers; the eclipse was observed under perfect weather conditions and results of the greatest importance

were obtained. Remarking upon his experience in organising eclipse expeditions, Sir Norman Lockyer says: "The extraordinary interest and the skill displayed by the officers and men of H.M.S. 'Volage,' under Captain King Hall in 1896, and of H.M.S. 'Melpomene,' under Captain Chisholm Batten in 1898, prove, I think, instruments according to the number it is intended to employ."

The eclipse of August 30, 1905, visible in North-West Canada, Labrador, Spain, Majorca, Algeria, Egypt, and Arabia, was of special interest because of the unusual extent and splendour of the corona and prominences then displayed. The recent



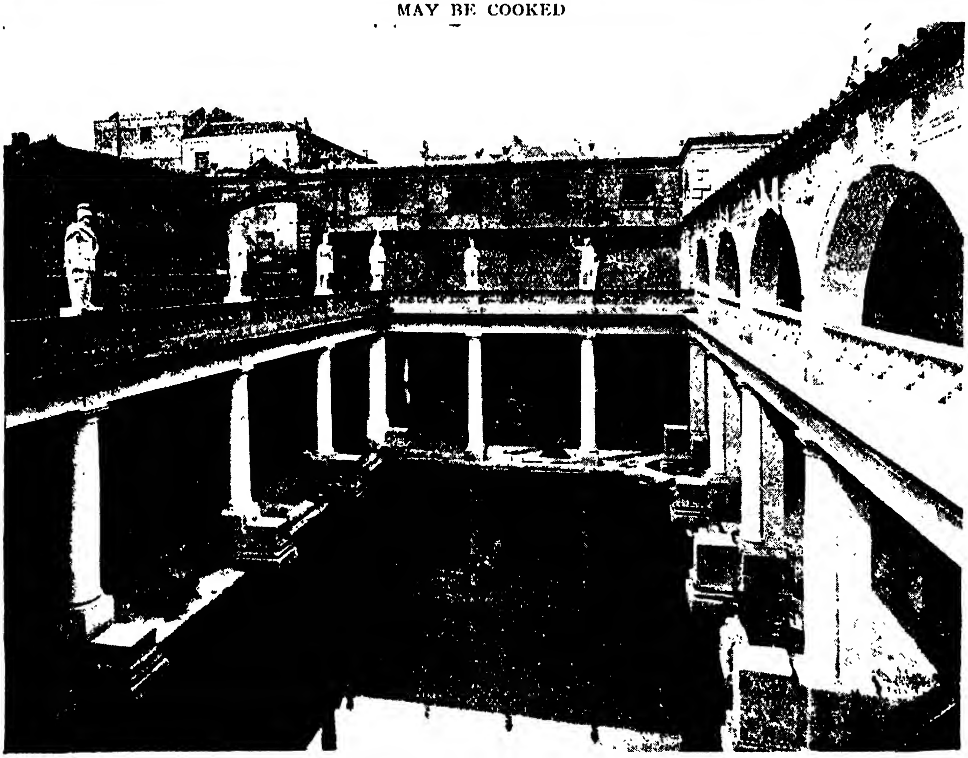
THE AWFUL STILLNESS OF AN ECLIPSE OF THE SUN THAT TERRIFIES BOTH MAN AND BEAST

beyond all question, that in eclipses in which a man-of-war can be employed, the most effective and most economical means of securing observations is to depend upon the naval personnel, one or two skilled observers being sent out to help in the final adjustments of

eclipse of April 17, 1912, which was visible in London as a partial eclipse, extended from Portugal to Germany, passing through France and Belgium. In Portugal it had a totality of three seconds, but by the time it reached Paris it had lost much of its interest and become an annular eclipse.

WATERS WARM FROM THE EARTH'S HEART

THE FISH POT-HOLE, YELLOWSTONE, NEAR WHICH FISH MAY BE CAUGHT AND WHICH THEY MAY BE COOKED



THE RADIUM-TINCTURED ROMAN WELL AT BATH, SOMERSETSHIRE

The photographs on these pages are by the Photochrom Company, Underwood & Underwood, Coles Finch, and others.

WATER STORES IN SPRINGS

Springs of All Kinds—Intermittent, Submarine, Fresh, Hot and Mineral, and the Wells that Give them Freedom

THE RESURRECTION OF THE WATERS

SOME rivers, as we have said, originate in springs. But how do springs themselves originate? To the untutored, unscientific mind there is something mysterious and miraculous about water gushing from a rock or bubbling out of a mossy hollow; and to the imaginative Greeks the springs were full of poetical suggestion. The springs of Hippocrene and Castalia still water Parnassus, and still the Grecian fountains sing of old stories. "One is the charming Acis, escaping from the lava rocks under which the Cyclops wished to overwhelm him; another is the nymph Arethusa swimming under the sea so as not to mingle her blue water with the troubled wave; another, again, is the virgin Cyane, bathing the flowers which she once gathered to weave a coronet for Proserpine." Even in comparatively recent days strange theories of springs were in vogue; it was long believed that springs were air condensed into water in subterranean chambers, or sea vapours condensed in cold caves. Now all mystery has gone; now we know that a spring is simply a resurrection of subterranean rain-water.

Let us look for a moment at the manner of this resurrection. As we have already seen, the greater part of the rainfall is not collected by the rivers but soaks into the soil. The depth to which the rain penetrates depends both on the amount of rain and on the nature of the soil. Clay and compact loam are very impermeable to water, whereas sandy and gravelly soils are very permeable. Vegetation assists the permeation of water, and some peat-mosses contain enormous quantities of water. The big peat-bogs of Ireland and Scotland, covering thousands of acres, must contain millions of tons of water. Where the soil consists of hard rock, rain penetrates with more difficulty; but even the hardest rocks, such as granite, are permeable to some extent; and the more porous rocks, such as limestone and sandstone, imbibe rain-water like a sponge. Stone taken fresh from a quarry is usually found to hold water—the so-called quarry-water. Necessarily, when rocks have imbibed all the water they can hold, they are no longer permeable, and rain runs off them as off a plate.

Now, suppose we have a layer of gravel resting on a layer of clay, what will happen? The rain will run through the permeable gravel till it reaches the almost impermeable clay. On the top of the clay the water will collect; and if, as is usually the case, the surface of the clay slopes or *dips* in a definite direction, then the water will run down the surface of the clay in this direction, until eventually it may find an outlet into the air, when it will issue as a fountain or spring. If, on the other hand, the clay should form a large concave surface, the water will gradually fill the concavity like a basin, and, pouring over its edges at one point or another, may find exit from the ground. Or there may be a crack or fissure in the overlying permeable gravelly soil, and the water, as it rises in the saucer, may rise into this fissure.

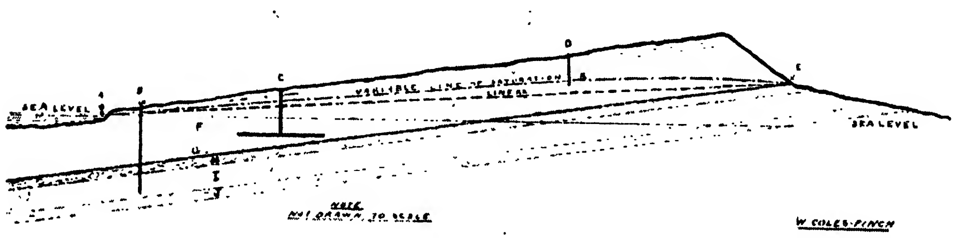
In other cases the water may take a labyrinthine course in various directions before it finds escape. Not uncommonly the water takes a V course, running down one arm of a V-shaped fissure and being forced up the other arm to its exit. In such a case the arm in which the water descends will be longer than the arm of exit; and the pressure at which the water rises will depend chiefly on the weight of the water in the longer arm compared with the weight of the water in the shorter. In many cases, springs of this kind go very

deep, so deep that they reach the hot, deep rock regions, and, getting heated there, issue as thermal waters. Of this nature are the hot springs of Bath, Baden, Carlsbad, Wiesbaden, Baden-Baden, and many others, and, as a general rule, the hotter the water, the deeper its source.

There are certain very interesting springs known as "intermittent," that flow freely for a certain length of time, suddenly cease, and then, after a certain lapse of time, begin to flow freely again; and this alternate ebb and flow may occur with great regularity for an indefinite period. One explanation of this intermission is simply that the water collects in a siphon-shaped cavity in the rock, and when it reaches a certain height it is siphoned off. Once the water is siphoned off, no flow can take place again until the water has risen to a certain height again. The principle is best explained by means of an illustration.

In some instances it is probable that the intermittent flow of springs is effected by gas-pressure. The gas accumulates in the rocky reservoir containing the water, and after a time acquires sufficient pressure to eject the water. Then there is a pause till the water and the gas accumulate again. The "English Well" in the canton of Berne, which flows a few hours every morning and again every evening, is probably regulated by gas. Other intermittent springs are due simply to intermittent supplies of water through the soil, such as is produced in certain districts by the melting of the snow by day and the freezing of it by night.

The depth water can penetrate is not known, but gravitation and capillary attraction certainly carry it down for great distances, and it is probable that it percolates down until the heat of the crust converts it into steam. The distance water



A DIAGRAMMATIC SECTION SHOWING THE DIFFERENT KINDS OF WELLS AND SPRINGS

A, submarine spring ; B, artesian well ; C, deep-well and adits ; D, ordinary draw-well ; E, surface spring ; F, porous rock, chalk ; porous rock, upper greensand ; H, impervious bed of gault clay ; I, porous bed of lower greensand ; J, impervious bed of Oxford clay ; line of saturation (variable) ; XX, line between outcrop of gault and the sea-level

Some of the springs showing siphon action are capable of accumulating and discharging immense volumes of water. Thus, near Portsmouth, there are some springs of this kind known as the Lavants. These springs undoubtedly take their rise in large underground caverns, periodically filled and then siphoned off. During the heavy rains of last winter they reached the point where siphon-action occurs, and a stream of clear and limpid water three feet deep issued at a rate equal to 25,000,000 gallons a day. This is a huge volume of water, and would suffice to supply Manchester or Liverpool.

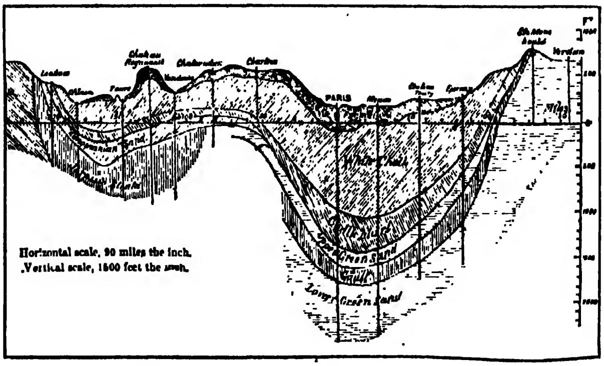
The regularity of some of these intermittent springs is very remarkable. In the Pyrenees, at Fontesorbe, a spring in summer flows for 36 minutes 35 seconds, and then intermits for 32 minutes 30 seconds. At one time there was a spring in Westphalia, known as the Bullerborn, which gushed forth every four hours with sufficient force to turn the wheels of several mills.

may travel underground before it issues as a spring may be hundreds of miles. The amount of water issuing from a spring depends, of course, mainly on the extent of the reservoir that supplies it. As a rule, the deeper and further the water travels before it springs forth, the more copious will the spring be, since depth and length imply a more extensive area of supply. In many springs the amount of water poured forth is very great. In Georgia there are springs which discharge 1400 gallons per minute ; in Virginia there are springs that discharge 6000 gallons per minute ; while the springs of Banff, in the Canadian Rocky Mountains, discharge fully a million gallons per minute.

If the subterranean reservoirs supplying a spring are much higher than its point of exit, the issuing water may form a natural jet. At Chatagna, in the department of the Jura, there is a natural fountain leaping to a height of 10 or 12 feet. In a grotto near Saint-Etienne there is a spring that

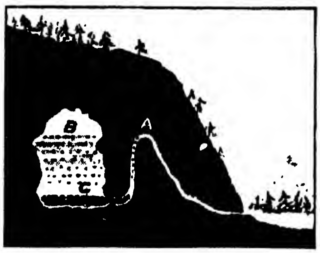
leaps about 24 feet in height. The tendency of all these fountains is to raise a conical mound of sediment round their orifice or exit until the top of the mound is as high as their jets of water. This has happened in the case of the famous Springs of Moses, on the shore of the Red Sea, where every spring is surmounted with its own little cone.

In some cases there are springs in the sea: "Fresh-water springs come up thro' bitter brine." In the Persian Gulf, for instance, there are such fresh-water springs, and boatmen sometimes dive into the Gulf and fill their water-skins with fresh water. These springs, which are warm, are probably supplied by the rain on the green hills of Oman, 500 miles away. It is certainly strange to think that the rain, falling on hills 500 miles away, should sink through the soil and eventually find an outlet from the earth in the Persian Gulf.



THE BASIN IN WHICH PARIS LIES - A SECTION

In many cases underground water does not naturally come to the surface, and can be reached only by boring wells; and in dry countries and deserts, where there are few rain-showers and no rivers, wells are essential to existence, and have been bored from time immemorial. Even the primitive dweller in the desert knows how to sink a well—the prime condition of life—and will sometimes attain a depth of about 100 feet.



AN INTERMITTENT SPRING

When the water rises to B all the water is siphoned out through A till it reaches the level C, when the outflow ceases until the water-level again reaches B

The modern water-finder, with his hazel rod, belongs to the category of charlatans, and his success is due to the fact that there is subterranean water almost everywhere, but the modern geologist and engineer, working together, have greatly developed the science of water-finding and the art of well-sinking. The geologist can tell the course probably taken by subterranean water, and the engineer will bore through clay, sand, and rock sometimes for hundreds of yards to give exit to the water. In the Algerian desert water is located by experts; and wherever a well is dug the water rises and the desert blossoms like a rose. Such prescience have geologists, and such confidence can be put in their predictions, that engineers bored through the soil at Calais to find and liberate water that had come from the hills of England.

The most important wells are known as "artesian." These wells depend upon a certain shape and disposition of permeable and impermeable layers of the soil. When a basin-shaped impermeable layer is covered by a permeable layer, and this again by a smaller, basin-shaped, impermeable layer, it follows that water can percolate between the two layers and accumulate there, just as water might accumulate between two saucers if a smaller saucer were placed in a larger one with a layer of earth between. It follows, too, that if a hole be made in the upper, smaller, impervious layer, the water between the two layers will rise in the hole. It follows, too, that the height to which the water will rise will depend on the curvature of the two layers, and the height to which the water rises in the permeable layer between. When the curvature is great, and walls of water rise high between the two impermeable layers, the weight and pressure at the bottom of the curve of impermeable material will be great; and if the water be given an outlet by boring through the upper impermeable layer, it will rise correspondingly high with corresponding force.

In the so-called London Basin an arrangement of this kind obtains. There is a curved layer of London clay covering permeable rocks of a sandy or chalky nature, which again is underlain by a second impenetrable bed of clay. In the case of the London Basin the curve is very slight, but, nevertheless, as soon as the upper layer of clay is penetrated, the water rushes to the surface, and

the whole of the London Basin is riddled with artesian wells. Unfortunately, this great underground reservoir is not inexhaustible; and some years ago the chief engineer of the London County Council reported that the level of the water in the chalk layer beneath London is falling at the rate of from 12 to 18 inches per annum. Also, when a well was sunk at Streatham some years ago, wells at Tooting, two miles distant, ceased to give water.

The amount of water abstracted from the chalk of England by some of these artesian wells is very great. The chalk spring near Ware, which is the source of the New River, discharges 4½ million gallons per day, and two artesian wells at Croydon discharge a million gallons a day.

In France we find the Paris Basin of much the same nature as the London Basin, and equally utilised for artesian wells. The Grenelle well, in Paris, is about 1800 feet deep, with a bore of ten inches, and it discharges at the rate of 517 gallons per minute. The Passy well is almost as deep, and discharges 5,582,000 gallons per day, throwing the water to a height of 54 feet above the surface of the ground.

A SURFACE SPRING ISSUING FROM THE FACE OF THE NORTH DOWNS AT HOLLINGBOURNE, KENT

Some wells give an even more copious discharge of water. Robert Brown, in "Our Earth and its Story," gives the following remarkable instance of an artesian well flood: "During the autumn of 1886 an artesian well in Bellaplaine, Iowa, by the violence and copiousness with which it spouted, threatened, for a time, to do serious damage to the town. Its diameter was four inches; and when the depth of 181 feet had been reached in boring, a volume of water rose, and rushed up with such impetus that it formed a *jet d'eau* several hundred feet high. This gradually increased in size and volume until a stream of water 16 inches in diameter was formed, and the upward force of the stream was equal to the force of gunpowder. Two 'gigantic rivers'—to quote the language of a correspondent—were accumulated by this outburst, which ran through the town at the rate of twelve miles an hour, carrying everything before them. The panic caused was naturally great. An attempt was made to insert 16-inch boiler-tubes into the well, but these were instantly blown out and forced high in the air. Fifteen cartloads of stone were then emptied into the well, but these were tossed upwards as though propelled by a charge of giant powder. For several days the flow continued unabated, and then gradually subsided to the more moderate discharge now characteristic of the well." This gives us some idea of the tremendous hydraulic pressure that can be exercised by subterranean water.

The depth of artesian wells varies. Some of them are hundreds, some thousands, of feet deep. One of the deepest in the world is the well at Sperenberg near Berlin, which is 4194 feet deep. In China there are several wells over 2500 feet deep.

Since the temperature of the crust of the earth progressively increases with depth, it naturally and necessarily follows that springs whose water has traversed the depths of the crust are heated more or less. Springs which issue with a temperature higher than the temperature of the soil are known as *thermal* springs. As we have already mentioned, the temperature of the Grenelle well, which is 1800 feet deep is 82 deg. Fahrenheit. The Bath springs issue at a temperature of 120 deg. Fahrenheit. The temperature of Kissingen water is 66 deg. Fahrenheit, of Plombières 149 deg. Fahrenheit, of Carlsbad 165·2, of Wiesbaden 158, of Baden-Baden 111·2 to 154·4. If we assume that the temperature of the water increases one degree Fahrenheit for each 60 feet of descent, it is possible to calculate the depth of the source of any spring. On this estimate the waters of Bath come from a depth of 4200 feet. But such calculations are not to be trusted too far.

SOME NOTABLE SPRINGS AND WELLS

THE FOUNTAIN OF ELISHA NEAR JERICHO

GIDEON'S SPRING: DRINKING AND LAPPING

THE MAORIS' WASHING-DAY IN THE HOT-SPRING DISTRICT OF NEW ZEALAND

DINNERS COOKING IN THE EARTH AT WHAKA, N.Z.

MAORI CHILDREN BATHING IN A HOT SPRING

The hottest springs in France are the springs of Chaudes-Aigues. The temperature of the water of this spring varies from 158 deg. Fahrenheit to 176 deg. Fahrenheit. The heat of the water, which is equal to the heat of combustion of four and a half tons of coal, is utilised by the townspeople in various ways. With the hot water they prepare their food, and wash their linen. "Wooden conduits, erected in all the streets of the town, supply on the ground floor of each house a reservoir which serves to heat it during cold weather, and thus dispenses with fires and chimneys. In summer, small sluices, placed at the entrance of each conducting tube, stop the warm water, and throw it back into the rivulet which flows at the bottom of the town." At Würtemberg the heat of a hot spring is utilised for maintaining a constant temperature in manufactories; and hospitals, conservatories, and fish-ponds are sometimes heated by the same means.

Such practical utilisation of the heat in the earth's bosom makes one wonder whether one day engineers will succeed in sending rivers down into the earth, so that, emerging again, they may supply the world with an inexhaustible supply of hot water. But all hot springs are not heated by the ordinary heat of the crust of the earth; some are heated by the heat of volcanoes. Among these must be counted the remarkable springs known as geysers, which we shall discuss in a later chapter.

All springs are in some measure mineral, since rain-water as it percolates through the soil must inevitably dissolve some of the mineral matter it traverses. The minerals most commonly found in spring water are lime and magnesium salts, especially the former. Limsetone is particularly pervious to water, and most springs percolate through limestone during some part of their career. The amount of lime water can gather in the course of its travels is well seen in the stalagmites and stalactites, in the incrustations that gather in boilers. Certain springs, the so-called *petrifying* springs, contain so much lime in solution that any foreign object, such as an egg or a bird-nest, placed in their waters becomes covered with a calcareous coating. It is true that carbonate of lime is almost insoluble in pure distilled water, but rain-water as it falls absorbs a certain amount of carbon dioxide from the atmosphere, and water containing carbon dioxide dissolves carbonate of lime quite readily.

A WATER-FINDER DISCOVERING A NATURAL SPRING DEEP IN THE CHALK HILLS

The deposition of lime round certain springs takes very picturesque and beautiful forms. Reclus describes the springs of Hammam-mes-Khoutine, in Algeria: "Most of the deposits are of a dazzling white hue, striped here and there with bright colours, and are developed in mammillated strata; other concretions accumulating gradually round an orifice have taken the form of cones and are like the small craters near a volcano, some of them rising to a height of as much as 33 feet; lastly, there are masses of travertin which stretch out in a kind of wall below the flow which deposits them. One of these walls, which is interrupted at intervals by heaps of earth upon which large trees grow, is not less than 4921 feet long, 66 feet high, and on an average from 33 to 49 feet wide." More remarkable still, he says, are the springs of Hierapolis, in Ionia, which flow over a plateau called Panbouk-Kelessi (Castle of Cotton), because of the cotton-like calcareous deposits which cover it. The deposit is 328 feet high and 2½ miles wide, and seen from afar it looks like a great cataract. When one gets nearer, one finds that the cataract consists of white crystal banks, over which dance down real cascades.

"As a spectator ascends the declivities the masses deposited and carved out by the water appear in all their strange beauty: and one might fancy that they were colonnades, groups of figures, and rude bas-relief which the chisel had not yet perfectly set free from their rough coverings of stone. Amid all these calcareous deposits, which have been fashioned by the cascades during a succession of ages, open a multitude of

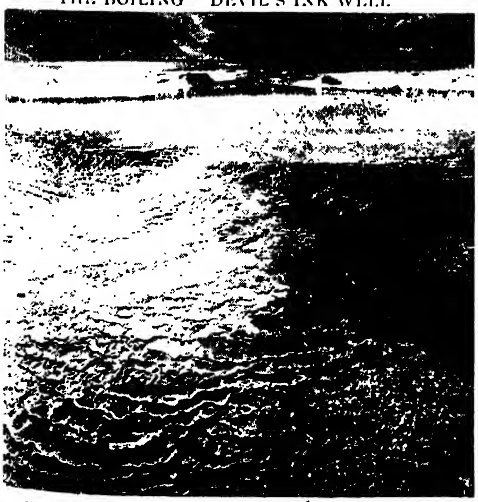
HOT SPRING SCENES IN YELLOWSTONE PARK

NEAR VIEW OF CLEOPATRA TERRACE AND POOLS

THE PETRIFIED PULPIT TERRACE

THE BOILING "DEVIL'S INK WELL"

THE BUBBLING "DEVIL'S PUNCH-BOWL"



OVERFLOWING SPRING MAKING A TERRACE

THE CLEOPATRA AND MOUNT TERRACES

cup-like hollows with fluted edges fringed with stalactites, and these graceful reservoirs, some of which are shaded with yellow, or veined with red, brown, and violet, like jasper or agate, are filled with pure water." Here and there there are the dried beds of rivulets; and "above one of the widest of these dried-up channels the magnificent span of a natural bridge displays its graceful form like an arch of alabaster, streaming with innumerable stalactites."

As we have previously explained, the deeper the source of the spring, the hotter the water, and the hotter the water the better solvent is it of mineral matter. In the extreme depths of the earth where there is hot water under tremendous pressure it is quite possible that even gold and copper and silver are dissolved. Certainly, very hot springs under high pressure dissolve the silicates out of granite and other rocks, and form precipitates of opaline silicate, which are sometimes singularly beautiful. There are such deposits around the geyser springs of Yellowstone Park and Iceland. Of like nature, too, were the famous Pink and White Terraces of Rotomahana, in New Zealand.

In a number of springs, common salt is the predominant element. The well of Sperenberg, near Berlin, the deepest well in the world, is brine. The brine is not derived from the sea, but is dissolved out of beds of rock-salt over which the water passes. Well known are the brine-springs of Droitwich, Cheshire, Wiesbaden, Cheltenham, and Saratoga. In many cases the wells bring up salt in commercial quantities. The salt *springs* of Salzburg and Halle produce thousands of tons of salt a year.

Some springs contain iron in notable quantities, so that their water has an inky taste. The water of the famous iron spring of Langenschwalbach contains, when fresh, ·37696 of protoxide of iron in 1000 parts. Sulphurous springs are fairly common, and are usually easily recognised by their characteristic smell of rotten eggs. Most mineral springs containing any considerable amount of mineral substances have medicinal properties, and all over Europe there are famous mineral springs frequented by thousands of invalids. Well known are Carlsbad, Vichy, Aix-les-Bains, Aix-la-Chapelle, Harrogate, Bath, Buxton, and Strathpeffer.

The medicinal value of the waters is undoubted, but there is a tendency to overestimate their value; and probably many cases of cure which are attributed to mineral water are really due to change of air and change of food at the watering-place. Recently it has been shown that many waters, such as those of Bath, contain radium; and it is possible that the healing virtues of various waters are due to radio-active substances contained in them. Apart from healing virtues, the mineral substances contained in spring water are of physiological importance; for water absolutely pure would be dangerous, or at least deleterious, to drink. The effect of pure water is to set up an osmotic flow, so that the cells lining the stomach and intestines absorb water, swell up, burst, and are destroyed. About the purest spring-water known issues from a spring at Gastein, in the Austrian Tyrol; and this spring is named the Giftbrunnen, or Poison-Spring, because of its pernicious effects. Besides mineral substances, spring water always contains a certain amount of the atmospheric gases, and in some cases the water bubbles and effervesces with carbonic acid gas. Within the last few years, too it has been shown that the water of certain springs contains an appreciable quantity of the rare gases helium and argon.

THE GUSHING SPRINGS. DRIVING ADITS THROUGH CHALK STRATA AND FINDING A FLOOD

MENDELISM UP TO DATE

Why should not Laws Constant in Relation to the Propagation of Plants Apply to Man?

LATEST RESULTS OF AMERICAN TESTS

It is not easy to keep pace with the progress of genetics unless we are prepared to devote ourselves to nothing else. The American school of Mendelians are adding to the student's task; but with the aid of the "Journal of Genetics," and Professor Punnett's admirable handbook, "Mendelism," which has had a sale that shows the widespread interest felt in the subject, we must attempt to set down the record of genetics at the present time. Very much has been done since Mendelism first began to attract the attention of men of science; and the new study has no better feature than that the successive results are trustworthy—for the good reason that they are the results of actual experimental observation. Heredity has never been studied in this way before, or similarly valuable results would have been obtained long ago.

The work done by Mendel himself has been entirely confirmed, and, what is more interesting, his theoretical interpretation of it has been confirmed also, and extended, by the "presence and absence hypothesis" of Professor Bateson, who explains dominant characters as due to the presence of something in the germ-cells, and recessive characters as due to the absence of something from them. The characters in question may be normal or abnormal, good or bad; and for every case it has to be ascertained whether it is due to the presence of something in the germ-cell, or the absence of something from it.

This simple interpretation of the dominance and recessiveness discovered by Mendel is the chief contribution to the theory of the subject since its rediscovery. Mendel rightly looked upon the gametes of his peas as bearers of something capable of giving rise to the characters of the plant, and he regarded any individual gamete as being able to carry one, and one only, of any alternative pair of characters - a given gamete could carry tallness or dwarfness, but not both. He regarded these two opposite characters as mutually exclusive so far as the gamete was concerned. It must be pure for one or other of these opposite characters, and this idea of the purity of the gametes is the most essential part of his theory. The "presence or absence" theory makes it intelligible; for if dwarfness be due to the absence of something which, if present, produces tallness, obviously every gamete will be pure in this respect; either the tallness factor will be present or it will not.

We have already seen that a tall plant, as in Mendel's experiments, may be of two distinct kinds. It may have nothing but tallness to transmit, but it may also have dwarfness to transmit, though that does not appear in itself, being overshadowed by the dominant tallness. In other words, the tall plant may be what we call a pure dominant, which will yield nothing but talls indefinitely; or it may be what is called an impure dominant, in which case half its gametes, on the average, will convey tallness, and half will convey dwarfness. No inspection of the individual plant will tell us to which of these classes it belongs, but that may be just the information we want. If, for instance, we want to breed a race in which the dominant character will be fixed, we must start with pure dominants, which have no dwarfness in them, for the purpose, and somehow we must distinguish them. But this can now be readily done, if we do not know the plant's ancestry, by the test of experimental breeding. We must cross such a plant with a pure recessive, whose gametes contain nothing but dwarfness. If the offspring are all tall, then it is evident that the tall parent is a pure dominant, producing nothing but gametes which carry the tallness, so that all the offspring are tall, though

from their other parent they get dwarfness. But if the tall parent be only an impure dominant, half its gametes will have the tall dominant character, and half will not. These mate with gametes none of which have the tallness in them, and the result is that the offspring of such a mating will be, on the average, half tall and half dwarf. Thus our experimental test, of crossing it with the recessive, has enabled us to say whether the plant showing the dominant character is a pure dominant, or an impure dominant bearing the recessive character. In the first case, all the offspring have the dominant character, and in the second they are half dominants and half recessives.

Illustrations of the Mendelian Method of Calculating Ratios of Breeding

We note also that these assertions hold good independently for any number of alternative characters in the same plant. For instance, in the pea, colour of the flowers may be dominant to their whiteness, as tallness is to dwarfness. The Mendelian law is followed in all crossings, so that we get a number of possible forms, and these occur, on the average, in ratios which can be readily calculated. Thus, as Mendel showed, if, for example, the parents differ in three pairs of character, A, B, and C respectively dominant to a, b, and c, the crosses will, of course, all be of the form A B C, but the next generation will consist of 27 A B C, 9 A B c, 9 A b C, 9 a B C, 3 A b c, 3 a B c, 3 a b C, and 1 a b c. The figures and symbols may be tiresome, but it will be seen at once what possibilities for the creation or "origin" of new forms, which may quite well be ranked as new species, are raised here.

Thus in the third generation, or the second filial generation in the modern terminology, we have six types of individual which did not exist before; and it may be possible, by appropriate means, to obtain individuals of these various types which will breed true. If we are dealing with wheat, for instance, instead of peas, such experiments may achieve more for agriculture than all the politicians that ever were or will be.

Some Terms Added to the Familiar Vocabulary of Students of Life

Two other recent terms, which we owe to Professor Bateson, must here be introduced, for they are very convenient, and will have to be part of the familiar vocabulary of students of life for the future. We have seen that a given individual, being formed by the yoking of two constituents, and being thus of double constitution, may be called a *zygote*, which means yoked. Now, any zygote may be of two kinds in respect of any Mendelian character. If that character (whether dominant or recessive) was borne by both of the gametes which were yoked to form the zygote, then, in respect of that character, the individual may be called *homozygous*, a fact which has the immensely important consequence that all the gametes borne by such an individual will bear the character in respect of which it is homozygous. The "pure dominants" to which we have already referred are thus to be styled homozygous; they are of similar origin from both sides, in respect of the character under discussion, and they will bear gametes of only one type in respect of that character.

On the other hand, a zygote may be formed by two gametes one of which bears the given character while the other does not. It is then said to be not homozygous but *heterozygous* in respect of that character. It will usually look and be, so far as itself is concerned, just the same as its homozygous neighbour, but it bears different gametes, for half of them will carry the given character and half will not. And here, again, the various pairs of characters are independent, so that any individual may be homozygous in respect of any character or characters, and at the same time heterozygous as regards others.

Where Bateson's Studies have Simplified Mendel's Original Views

We have just used the expression "pairs of characters," and now let us look more closely at what is apt to puzzle us. Why should characters be arranged like this in pairs? Mendel's own explanation of his discovery was that "in the gamete there was either a definite something corresponding to the dominant character or a definite something corresponding to the recessive character, and that these somethings, whatever they were, could not co-exist in any single gamete." These somethings are the Mendelian factors, as we now call them, each of which corresponds to a unit-character in the developed zygote. It does not appear evident, however, why characters should exist in alternative pairs like this, and why there should be this impossibility of the simultaneous presence of, say, the factor for tallness and the factor for shortness in a single gamete. Professor Bateson's experiments and arguments have beautifully simplified Mendel's original views, and have made the facts reasonable. They are *not* opposite factors, as Mendel supposed, which produce opposite

characters, and which, for unknown reasons, can never go together into a single gamete. On the contrary, all contemporary students accept the "presence and absence" theory of Bateson, to which we have already referred, but which is so important that it may be briefly defined again in Professor Punnett's words:

A Simple Statement of the Modern Theory by Professor Punnett

"On this theory the dominant character of an alternative pair owes its dominance to the presence of a factor which is absent in the recessive. The tall pea is tall owing to the presence in it of the factor for tallness, but in the absence of this factor the pea remains a dwarf. All peas are dwarf, but the tall is a dwarf plus a factor which turns it into a tall. Instead of the characters of an alternative pair being due to two separate factors, we now regard them as the expression of the only two possible states of a single factor, namely, its presence or its absence." Here, then, is the simple explanation of the otherwise extraordinary and baffling fact that in all cases of Mendelian inheritance we can express our unit-characters in terms of alternative pairs, and we are able to formulate a definite conception of the living body in such terms as these, lately laid down by Professor Punnett: "A plant or animal is a living entity whose properties may in large measure be expressed in terms of unit-characters, and it is the possession of a greater or lesser number of such unit-characters that renders it possible for us to draw sharp distinctions between one individual and another. These unit-characters are represented by definite factors in the gamete, which in the process of heredity behave as indivisible entities, and are distributed according to a definite scheme. The factor for this or that unit-character is either present in the gamete or it is not present. It must be there in its entirety or completely absent."

The Interaction of Many Factors in Producing Varied Characteristics

This is a very definite and simple start, but most interesting complications soon arise. The factors, as we now assert, are independent in the gamete, each is distributed in subsequent generations according to its law as if the others did not exist. When we are dealing, as Mendel did, with factors that affect entirely different parts of the plant, that is all clear enough. But when we come to study separate factors which nevertheless affect the same part of the plant we soon see that, so far as the zygote is concerned, factors often interact and produce strange and unexpected results in the zygote or individual body from their interaction, though they each go their own strict way in the gametes from generation to generation. Thus, for instance, it is possible to cross certain white sweet-peas, and produce nothing but coloured—say, red—offspring. It is like a chemical experiment in which two colourless fluids are mixed and a brilliant red precipitate results. And, indeed, the analogy to a chemical experiment may be more than an analogy. It may be—nay, must be—just such an experiment that we have performed in this case. The red colour in the sweet-pea results from the interaction of two factors, like the mixing of the two colourless solutions in our chemistry. Unless both of these factors are present, the red colour cannot appear. Now, in each of the white parents one of these factors was present. The cross between them brought the two complementary factors together; they produced their mutual interaction, like the solutions in a test-tube, and so all the resulting flowers were red.

An Illustration of Genetic Interactions from Chemical Science

Naturally, this red precipitate, so to call it, which has been deposited in the petals by this process, becomes of rare chemical interest. Can the chemists extract it for us, and find, perhaps, that it is a salt made of an acid and a base, like some red salt of iron that can be made in the chemical laboratory? In this case, as probably in others of the kind, it seems clear that a chemical process of a rather different kind is at work, but yet one which depends upon the interaction of two distinct substances. Probably there is a colourless substance, or rather a white substance, which has certain potentialities, so that it may be called a "chromogen," or colour-begetter. This substance can scarcely itself exist in a gamete, but the conditions which produce it in the developed flower must do so, and one of the white parents makes this contribution, apparently. Now, what this chromogen requires in order to form a red pigment is some agent which will partially oxidise it—in a word, an oxidising ferment. Probably, then, the second white parent contributes this ferment, or rather a factor which leads to the formation of this ferment, in the gamete which it provides. When the chromogen from the one gamete and the

ferment from the other meet, the chromogen is oxidised and the red pigment is produced.

This is not to be taken as quite proved, so far, and we have somewhat simplified the facts for the purposes of the argument; but it will now be clear what is meant by interaction of factors, and why we are entitled to say that the production of red from the mixture of two whites has more than an analogy to the feats of the chemist with his test-tubes.

Ultra-Microscopic Complexities of Constitution Revealed by Mendelian Study

But this is merely the beginning, though an immensely important one. It teaches us that apparently simple things may be due to the interaction of distinct factors. If this be true for redness in sweet-peas, how much more is it not likely to be true of, say, genius in man? It is not too much to say that no thoughtful person can seriously look at these recent Mendelian discoveries without once and for all forming new notions as to the complexity of the constitution of living things, and, above all, of the highest and most complicated species we know. Observe, further, that here experimental breeding reveals complexities of constitution and composition which no knife or scalpel and no microscope could ever reveal. This is something subtler and more minute and more profound than microscopic anatomy, or even physiological chemistry. The anatomist may trace the pigment to certain parts of the petal, and the chemist may extract and analyse it. But only the Mendelian can peer so much deeper than either as to tell them that this pigment is essentially a double thing due to an ingredient derived from one parent, and a second ingredient derived from the other.

A Theory that Equally Explains New Characters and Reversion to an Ancient Type

The interaction need by no means be confined to two factors. Thus coloured stocks may either have the leaves and stem covered with tiny hairs, or those hairs may be absent. No method of investigation but one can tell us anything more about these tiny hairs than that they are there, and have the ordinary structure of such hairs. But experimental breeding has proved that the presence of even such a simple and unimportant character as this is due to the necessary interaction of three factors. Unless all three meet in the zygote the hairs cannot appear, but those three factors are separately distributed in the descendants, according to the ordinary Mendelian law. Imagine the hopelessness of trying to study the inheritance of this hairiness by the old methods, finding it come out of nowhere, and go nowhere; and the contrast with the Mendelian method, which reveals the order of inheritance and the constitution of the individual at one and the same time!

We are not to suppose that the interaction of factors is necessarily of the types described above, though they illustrate it so well. Sometimes, as we have seen, a new character appears from the conjunction of two factors; or this "new" character may be of immense antiquity, as in those cases of reversion where the appearance of the ancestral form in the crosses is due to the coming together of two factors which have long been separated in the course of evolution. But the new character, or the reversionary character in some cases, may no less be due to the absence of two factors in the zygote, the absence of one having been "contributed," so to say, by each gamete concerned. Only in the zygote in which just these two factors are absent can the new or old character appear.

The Inhibitory or Arresting Action of One Factor on Another

Yet again, factors may interact in other ways. The zygote may inherit from one gamete a factor which would naturally produce such and such a characteristic. But from the other gamete which goes to its constitution it may inherit a factor which inhibits or arrests the action of the first, and so the character in question cannot appear. For instance, wheats may be bearded or beardless. The presence of the beard is here palpably something additional to the structure; and we might reasonably expect, on the "presence and absence" theory, that the bearded condition will be dominant, due to the presence of the factor for the beard, and the beardless condition will be recessive. The reverse is the case, however. The beardless condition is dominant, and the explanation is that it is due to the presence of a factor which prevents the beard from growing. An obvious illustration of the difference is the case of the beardless boy, and of the beardless man who is beardless because of a positive factor the presence of which prevents the appearance of his beard—namely, his razor. In short, the same visible effect may be produced, in many instances, either by the omission of a factor, or by the addition of a factor which has the preventive or suppressive action. Thus dominant and recessive white poultry are indistinguishable

in appearance, but the former contain a factor more, and the latter a factor less, than the coloured bird. The foregoing, especially in those cases where the interaction of factors, meeting again after ages of separation, produces a reversion to the wild or ancestral form of the species, obviously bears upon one of the great evolutionary questions—the relation of wild forms to domestic varieties.

Why New Characters Sometimes Appear Suddenly and Complete

The classical idea is that the domestic forms have been produced by the long and patient continuance of selection; and, as we remember, Darwin argued from this artificial selection, carried out by man, to what he called "natural selection," carried out by Nature, and similarly originating new species there. But, in point of fact, as for instance in the sweet-pea, the new character does not arise from a pre-existing variety by any process of gradual selection. It turns up suddenly, complete in itself.

Something has happened in the gametes; and our experiments show us what this something has been in many cases. If the bringing together of factors often yields us a reversion to the wild form, it must be that the domestic variety was formed by the dropping out of certain factors, and that is the simple relation between them. Some of the domestic varieties are due to the lack of one factor, some to the lack of another. Put them together, and we have offspring in which all the factors once associated again meet; and the phenomenon of reversion on crossing, about which so much astonishing nonsense used to be written, is at once explained. This seems to be clearly true of many species, including sweet-peas, rats, and rabbits.

Cases of Apparent Attraction and Repulsion Between Genetic Factors

In other instances the action appears to have been of an opposite kind, and the more recent form is due to the interpolation or addition of a new factor which was not present in the ancestor. This appears to be the case as regards the colour and some other characteristics of wild and domestic pigeons, and the same seems to be true of the hornless or polled condition of cattle. Their wild ancestors were, no doubt, horned, and the hornless state has been shown to be dominant, like the beardless state of wheat. Here, then, a new factor has been added in the course of evolution, though its action is an inhibitory one, and though at first sight we should naturally suppose that the modern hornless cattle had lost a factor which produced the horns in their ancestors. The fact is that they have gained an inhibitory factor, like modern man with his razor.

We now come to a new and most important complication. We have already seen how factors may interact, but all the factors under discussion are transmitted independently. So far as transmission is concerned, each behaves, we have insisted, as if the others were non-existent, though their interaction produces such marked results upon the zygote or individual. But now we encounter cases where the factors do affect one another in their transmission—cases where they repel one another, so that they seem to decline to enter into the same gamete, and other cases where they seem to enter into the same gamete by preference. This problem may be summarised as that of the repulsion and coupling of factors; and a moment's thought will show what large consequences may be involved, above all for the case of man, if the factors for certain characters, desirable or undesirable, have a tendency to be habitually linked in heredity with factors for other qualities, or simply decline, so to say, ever to be combined with certain other factors.

The Suggestion by Genetics that the Sex of an Individual is One of Its Mendelian Characters

These phenomena clearly show that there may be natural limits to what even experimental breeding may do, no matter how definitely the laws of transmission are known. The reader is carefully to avoid confounding this new problem with the primary one—that opposites cannot go into the same germ-cell. That, we said, meant that opposites are due to the presence or absence of one thing, called a factor, and that the factor must plainly be either present or absent in any given case. But now we learn that sometimes factors which do not stand for opposites, and would appear to have no relation at all, repel each other, or are coupled with others, in the process of gamete formation, or gametogenesis.

The practical importance of this will be evident when we consider it in relation to the phenomena of sex. As has been already hinted, the modern developments of genetics demonstrate that the sex of an individual is one of its Mendelian characters, or is at any rate based thereon. And it may well be, as many instances suggest, that the

factors for sex, male or female, are especially liable to repel, or to couple with themselves, other factors that have nothing whatever to do with sex as sex, but may yet have the result of giving certain characters to individuals of one sex as compared with the other.

No one can look at the familiar Mendelian ratios—as, for instance, the half and half which we see when we cross an impure dominant with a recessive—without remembering that, on the average, the offspring of male and female parents exhibit the same ratio as regards their sex. Might it not be, then, that one of the sexes is an impure dominant, being heterozygous in respect of a factor which the other does not possess—a factor which determines the sex?

Cases in which Maleness and Femaleness are Equally Balanced

At any rate, in some instances it appears to be the case; the female possesses a femaleness factor which is absent in the male. But she is heterozygous in respect of this factor, not having received it in the gamete from the male parent. Hence, adopting the usual symbols and calling the dominant factor for femaleness F, and its absence f, we find that the constitution of the female is Ff, and of the male is ff. This being so, we should expect the numerical proportions of the offspring to be half male and half female, as in all other cases where an impure dominant is mated with a recessive. All the gametes from the male are without the femaleness factor; on an average half the gametes from the female will have the femaleness factor, or F, and half will be without it, and so the offspring will be half composed of f × F, and half of f × f—half female and half male. This we here assert only for certain species; the case may be quite different with others.

The Likelihood of a Scientific Foundation for Sons Resembling Mothers

Various instances of coupling and repulsion between the factors for sex and the factors for other characters have been met; and Professor Punnett's conclusion as to the particular case of the brown Leghorn hen is too interesting not to be quoted: "The mother transmits to her daughters her dominant quality of femaleness, but, to balance this, as it were, she transmits to her sons another quality which her daughters do not receive. It is a matter of common experience among human families that in respect to particular qualities the sons tend to resemble their mothers more than the daughters do; and it is not improbable that such observations have a real foundation, for which the clue may be provided by the brown Leghorn hen."

The case of this hen shows that a certain factor cannot enter, by a double dose, one from each side, into a gamete which also contains femaleness. She can give her daughters a single dose of this particular factor, but that is not enough. At any rate, we know that in some cases the qualities of an individual are markedly different according as to whether he or she has received a single or a double dose of a given factor. Hence, as Professor Punnett argues: "It is not inconceivable that some of the qualities in which a man differs from a woman are founded upon a distinction of this nature. Certain qualities of intellect, for example, may depend upon the existence in the individual of a double dose of some factor which is repelled by femaleness. If this is so, and if woman is bent upon achieving the results which such qualities of intellect imply, it is not education or training that will help her. Her problem is to get the factor on which the quality depends into an ovum that carries also the factor for femaleness." This may require much comment and qualification, but it is a suggestion too interesting to ignore.

The Wide Application of the Mendelian Law to Man now Certain

For undoubtedly modern genetics comprises man. The Mendelian law has been found to apply in so many diverse species of animals and plants that the probability of its application to man has been increasing year by year. Genetics today can demonstrate its laws in such various cases as the height, hairiness, flower-colour and flower-form, the shape of the pollen grains, and the structure of the fruits in plants; the coat-colour of many mammals, the form of the feathers and the comb in poultry, the waltzing habit of Japanese mice—and now man must be added.

A long-standing objection is to the effect that, in the United States, there are a large number of mulattoes—children of white people and negroes—whose skins are intermediate in colour, and whose offspring are like them. In point of fact, this question has not yet been properly worked out, and should not be pronounced upon. But several families have been described, of unions between white people and Indians, where there is clear evidence of the segregation of the colour, and its behaviour in

a fashion which will doubtless be reduced to the Mendelian law.

It has also been definitely shown that the inheritance of certain constituents of eye-colour is Mendelian, brown being dominant to blue. This is at present the only normal human unit-character that has been definitely shown to obey the Mendelian law, but the existence of one such character speaks volumes for what future inquiry may be expected to reveal.

The Mendelian Rules of Heredity Shown in the Transmission of Human Abnormalities

As for the human abnormalities which have lately been shown to be Mendelian in their transmission, their number increases month by month. There is, for instance, an unusual deformity of the fingers and toes, known as brachydactyly, or short-fingers, in which the fingers and toes have only two bony segments instead of three. This is a defect in the number of anatomical elements, but it has been shown to be a Mendelian dominant, due to the presence of something which is not present in the normal gamete. The demonstration is of practical moment, for it means that unaffected individuals from the affected stock cannot transmit the defect. They are recessives, and their children will remain so, like all other normal people.

Several peculiarities of the skin and of the front parts of the eyes, including the lens, which are formed from the skin, have been shown to obey the Mendelian law in man—such as a peculiar tendency to blisters, a no less peculiar thickening of the skin in the palms and soles, and cataract (opacity of the lens) which comes on in early life, instead of in old age, and is hence known as pre-senile cataract.

The Mendelian Law in Relation to Certain Forms of Blindness

Elsewhere in this work it has been shown that certain mental conditions are also Mendelian, the peculiarity in these cases behaving as a recessive, unlike the case of brachydactyly. Certain nervous disorders, affecting the spinal cord and its nerves, including one which was first identified by the famous English physician Sir William Gowers, and is named "Gowers' disease," after him, must also be included in this category. There is also the extraordinary record of a family in which many members are "night-blind"—*i.e.*, unable to see at all in moonlight or twilight, the retina being insensitive to light which is quite sufficient to excite it in normal people. The records here go back to early in the seventeenth century. More than two thousand descendants of a "night-blind" individual then born have been recorded. For ten generations and nearly three centuries this peculiarity has been transmitted as a Mendelian dominant.

Finally—for the present—there is the group of strange human cases in which the factor concerned in the peculiarity and the factors for sex are somehow coupled or repelled. Thus, in colour-blindness, almost invariably; in the disease known as hæmophilia, which is an abnormal tendency to bleed uncontrollably from slight causes; and in various conditions of the eyes and the nervous system, the general rule is that "males suffer and females transmit." In some of these cases a simple interpretation would be that the abnormal character is dominant in males and recessive in females. The women in such instances are free from the defect, and so are their daughters, but it appears in their sons. As to the children of the affected males, we have not yet sufficient evidence.

The Immeasurable Promise the New Science of Genetics Makes to the Future

Such is the extreme limit to which this great new science of genetics has attained at the time when these words are written. The extent of its promise, within its appointed limits, is immeasurable. As we have seen, it is giving us an analysis of what appear to be simple and single characters of the individual body the real nature of which could have been ascertained in no other way. It is enabling us to construct new living forms, which breed true, and which may be very useful. But it essentially deals with characters or factors which are already presumed to exist. It re-shuffles them, but does not create them. Though entire novelties may appear, such as might be called new species, they are only due to a novel combination of factors already existing. But, plainly, there are deeper questions. The highest forms of life contain more factors than the lower. Where and how did those new factors come into existence? Here is room for experiment of an entirely distinct kind, which no one has yet attempted in this country, but on which some notable pioneers are now working in America; and to this experimental biology, as it is called, we must next direct our attention. But here we are without any such key as Mendel provided, and we may yet have to acknowledge that we are in the presence of the ultimate—the creative force of which all life is the manifestation.

PLANTS THAT DIE IN FULL SUNLIGHT

FERNS BY A STREAM, WHERE LITTLE SUNLIGHT PENETRATES THE OVER-ARCHING ALDERS

THE BARE PATCH IN A WOOD WHERE TREES HAVE BEEN FELLED FOR A YEAR, WITH THE RESULTANT DEATH OF THE SHADE-LOVING UNDERGROWTH THAT FLOURISHED LUXURIANTLY

The photographs on these pages are by Messrs. Hinkins & Son and Mr J. J. Ward

A PLANT'S FIGHT FOR LIFE

Some of the Special Arrangements by which Accommodation to Changing Circumstances is Secured

THE EXTERNAL RELATIONS OF PLANTS

The physiology of plant life, which we have now under discussion, embraces a very great number of processes, all devised to render the success of the plant more probable, and some of these processes are of a very complicated nature. We have studied in a general manner what may be termed the primary physiological processes upon which the very existence of the plant depends. That is to say, we have paid some attention to the nature of seeds and their germination ; the production of roots, and stems, and leaves ; and the necessity for obtaining from the soil and the air such substances and elements as are needed for the manufacture of protoplasm. But in all these cases, up to the present, we have been assuming that the plant has no special difficulty to overcome in carrying out its functions, and we have therefore had no occasion to study any special arrangements which may be required in the face of special difficulties.

It can be readily understood that in the infinite variety of the species of plants and trees which constitute the flora of any country, the struggle for existence and survival must be an extremely acute one in natural conditions. It is not surprising, therefore, to find that an enormous number of very special adaptations to environment are to be found in connection with plants. It is to the more detailed study of these special arrangements that we must now devote some little attention.

The problem is how the plant may best adapt itself to its external relations in so far as they are of such a nature as to demand the making of some special provision. The external relations of a plant to which it must successfully adapt itself are those especially which have reference to the amount of water or moisture surrounding it ; the presence or absence of sunlight, and the effort to obtain such as there may be ; the peculiar character of the soil in which the plant happens to find itself, and which may not be all that is most desirable for that particular species ; the special constitution of atmosphere in the locality, and other factors of a similar nature. Then, too, there is the great question of the protection of the plant from the destructive tendencies of animals, and the efforts which plants must make in order to survive a time of drought, and so forth. All these are what we may term the "external relations" of plant life, the factors in the environment in connection with which the plant or the tree is to make its effort for survival ; and their mere enumeration is at once sufficient to indicate that there will be an immense variety of circumstances, or combination of circumstances, in the presence of which, unless plants evolve some special arrangements for their own safety, survival would be impossible.

In our last chapter we studied the structure and functions of leaves, and some of their movements. We may therefore first of all turn our attention to the arrangements made by which leaves are so exposed to sunshine and air that they may best carry out their functions. The reader is urged to examine for himself the arrangement of the leaves on a considerable number of plants and trees, some of which we shall mention. Such careful personal observation will indicate the necessity of the adaptation to external relations we are now considering.

In the case of some of our native trees, such as the elm, the oak, the beech, and the apple, the arrangement of the leaves is that of a spiral around the stem, coming off from vertical shoots. If the direction of the stem be noted in its natural position, in reference to that of the arrangement of the

leaves, it will be seen that here the arrangement gives the maximum exposure to sun and air. Where twigs are not vertical, but horizontal, such as some of those in the elm, and the beech, and the chestnut, the same result is secured by a different arrangement, in which the leaves are in two flat rows, one on each side of the twig. In many trees that have leaves placed opposite to each other, each pair of leaves occupies the space of the leaves immediately below, as may be excellently seen if one looks down vertically on a shoot of the horse-chestnut. Similar arrangements of a very perfect kind will be noted by observing many of our climbers as they cover the walls of a building. The arrangement of the leaves in the horse-chestnut just mentioned, if examined at the end of a shoot, has been termed a "leaf mosaic," on account of the pattern formed when looked at vertically. Another device which obtains in many plants for a similar purpose is the dividing of the leaf into very delicate divisions like a fringe, a good example being observable in the leaf of the carrot. A glance at such a leaf shows that, while it will obtain as much sunlight as possible, it still does not shade the leaves below it—at any rate, not completely. Moreover, such a divided leaf is in less danger of laceration from strong winds.

PRICKLES FOR DEFENCE AND CLIMBING—WILD ROSE AND BRAMBLE

STINGING HAIRS ON A NETTLE STALK

This magnified photograph shows the stinging hairs, which consist of sharp, brittle tubes, closed at the apex with a tiny bulb, and each with a bag of formic acid at its base.

We saw in our last chapter that green colouring-matter in plants, in the presence of sunlight, plays an important part in the physiology of a plant. But it must have occurred to some readers that there are plants which have no chlorophyll at all, and live in situations where light never penetrates. Such plants belong to the group of fungi, and they subsist upon the small quantities of organic matter rain-water carries with it into the nooks and crannies and the dark places where they flourish.

When we come to examine the plants growing in caves and underground mines, or in pits and wells, where there is a certain amount of penetration of light, even if not very much, we at once find that the plants are principally of a green character. Not only so, but the green colouring of vegetation within caves is often luxuriously brilliant, and may appear even more vivid than that of an ordinary plant in the open air. Examples of this fact may be seen in the liverworts, and in many of the mosses and some of the ferns that flourish in these situations. In such cases the chlorophyll granules are developed in a very special way, for the light falling upon the cells is concentrated on the granules themselves, which thus receive a sufficient supply for their special functions.

There is another situation in which plants receive a minimum amount of light, namely, in the depths of the sea, or at the bottom of lakes and ponds, where sunlight is present in a very enfeebled condition. The presence of light under water diminishes in proportion to the depth. Two hundred mètres below the surface of the sea (about 600 feet) it is completely dark. At a depth of 170 mètres, the illumination is about equal to that at the surface of the water during moonlight; and this degree is not sufficient to enable plants possessing chlorophyll to manufacture

the complex substances we studied in our last chapter as being formed in ordinary green plants in sunlight. The greatest depth at which the chlorophyll cells can decompose carbonic acid is 90 mètres, and at this depth the process can only be carried on in clear, transparent water during bright sunshine. Such combinations at such a depth are, of course, uncommon, especially as the plants may be growing on a sloping surface, and so receive the light at an angle; and, as a matter of fact, plants possessing green colouring-matter are rarely met with at a depth of more than 60 mètres. The vegetation of the sea, speaking generally, is found within a space of some 30 mètres deep, so that we may regard the depths of the ocean as devoid of plants as we know them.

THE ARRANGEMENT OF THE LEAVES OF THE CARROT

It must also be remembered, in connection with the sea, that plants living therein are surrounded by blue light, and the more salt the water the deeper is the blue. Therefore, the conditions are very unfavourable for growth at great depths, especially as the particular rays of light which the chlorophyll requires (the red, yellow, and orange rays) are abstracted as the light passes through. On this account a very simple yet remarkable adaptation has been evolved by plants that find themselves in these conditions. Instead of the green colouring-matter, we find a red pigment, in addition to, or in excess of, the green. It can absorb a large quantity of the light falling upon it, and, moreover, the blue rays are changed by it to those rays which act upon chlorophyll. As Kerner says: "Green has given place to red. Sometimes a delicate carmine, sometimes a deep purple; then again a light brownish-red and a dull, dark crimson; and as we admire in the bush the innumerable gradations of green colour, so is the eye delighted in the manifold shades of red in which the different variegated species of Florideæ, intermixing with one another, display themselves."

If we now turn our attention to the flora found on the rocky slopes just above the sea-level, but still exposed to the spray in wild weather, we might expect to find—considering we are in the presence of direct sunshine—that the plants would now be of the usual green. Instead of that, they exhibit foliage of a grey colour with leaves and stems covered with white hairs, the whole being matted together. Another marvellous adaptation to external conditions is here, and one which has been rendered necessary for precisely the opposite reason to that which we saw in the great depths. There the light was deficient; here the surface of the rocks is too glaring. In both cases the chlorophyll granules must be modified in some way to meet the exceptional situation. Too much light may be just as harmful as too little; and so these plants on the sun-exposed rock have evolved a special covering of a silky or woolly nature, by means of which they are protected from the too brilliant light.

VERTICAL TWIG OF A CHESTNUT

This injurious effect of brilliant sunshine upon some of our most beautiful green

plants is a point that should be carefully noted. An excellent example of it may be seen when a clearing is made in what was before a dense portion of a wood, and, as the result, the leaves of the trees, that formed a protection to the undergrowth, are removed. Within a week or two the delicate plants and ferns of vivid green of the exquisite floor under the shaded trees have withered. In this case we are face to face with an inability on the part of these plants to adapt themselves to the new conditions, and the flood of light thus thrown upon them is an actual cause of death.

Next we may note that special protective arrangements are found in connection with plants that live the whole of their active life in climates or circumstances where the full power of the sun is felt from its rising to its setting. To avoid injury from this excess of light, certain structures of a hairy character are developed and cover the surface of the leaf, giving the latter a greyish or whitish tinge. If they be removed, the leaf underneath is found to be perfectly green. So here we have a sort of awning erected to shade the chlorophyll from excessive light. No wonder, therefore, that these hairy, silky, or woolly growths are widely found amongst plants.

MOSS, THE CARPET OF THE SHADY WOODS

Another arrangement devoted to a similar purpose is that of the production of blue colouring-matter in leaves and stems much exposed to light. We find a similar thing in the leaves and stems of Alpine plants grown in the heights where sunlight is extremely powerful. These structures are of a dark violet colour. All these adaptations are examples for the protection of chlorophyll—adaptations to external relationships.

The position of the leaf surface itself, with regard to the direction of the rays of the sun, is also a matter of great importance. The rays that fall upon a vertical leaf surface at morning and evening have just the required intensity for the functioning of chlorophyll. So we never find such leaves in the dark, shaded spots. The iris does not grow in a dense wood, but on the ridge of a mountain or an open plain; and should it be planted in a shaded locality, the leaf surface does not adopt the vertical attitude, but turns until its broad surface faces a diffused light. Should the light come from above, the leaf may even assume the horizontal position.

A cursory examination of the small plants growing under large shady bushes—indeed, of all the plants that grow under the shadow of larger ones—will show similar adaptations for the reception of sunlight. The two kinds of plants exhibit no sort of mercy to each other. They struggle to exist, one against the other. It is only when we come to the single plant that we find evidence of the adaptive change which is evolution. That is to say, it is the different parts of the plant itself which are concerned in helping the whole individual to survive. No individual plant will help anything but itself. Hence we find that in connection with the leaves they must be so arranged that one does not take the light from the next; must not injure its next neighbour when it turns; must not secure all the exposure, and so forth. But it must so adapt itself—as if by actual foresight—that the different members of the same corporate body so co-operate that the whole is benefited.

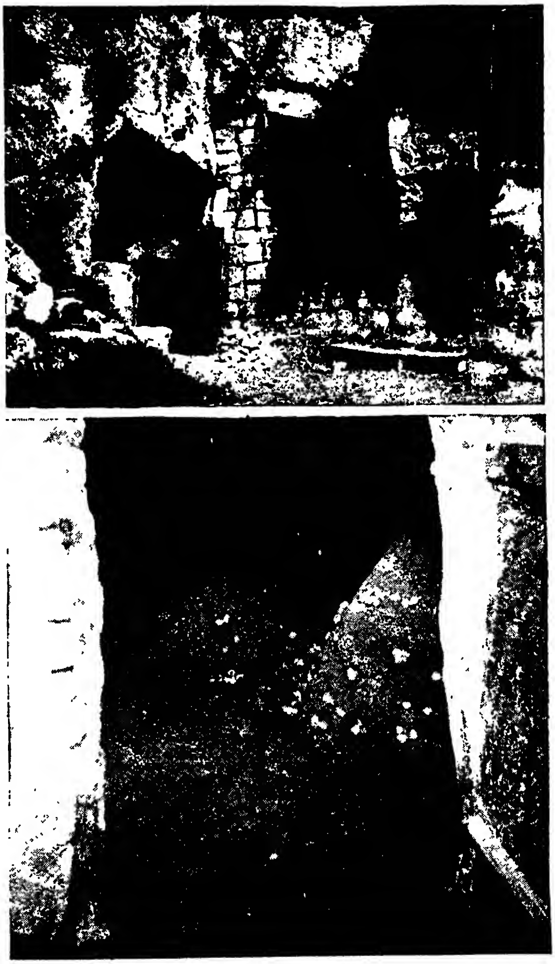
Quite a number of special forms of adaptation to environment may be studied in connection with water-plants, or hydrophytes, that live their entire life in a medium of water, and die when exposed to the air. Such plants very frequently exhibit quite special methods of reproduction. Thus they may show the formation of special embryonic cells, which, for a time, live a free life, swimming here and there in the water, until they either find, or are deposited in, some spot suitable for growth, when they adapt themselves, and for the rest of their life remain fixed.

When submerged plants are free from attachment, they are found to be living in practically still water, such as that of

ponds; and these plants may have no roots at all, for the simple season that they have no use for them. Moreover, they may pass part of their life at the bottom of the pond, and another part at the top, producing during the latter phase new leaves, and perhaps even flowers, sinking once more to the bottom when this stage is over. Examples of this mode of life are found in the plant called the "water-soldier."

The majority of hydrophytes, however, are attached to some fixed point. But a very interesting difference is to be noticed here as a comparison with that which obtains in ordinary land-plants. The attachment of a land-plant by its root serves to fix the plant in position, but it also serves the still more important function of abstracting nourishment from the soil at the point of attachment. In the water-plant, however, there is no such nutritive function carried on at the point of attachment; and hence the composition of the material to which the plant is attached is a matter of comparative indifference.

The food of water-plants is absorbed from the water in which they live through practically the whole of their surface, and therefore there is no occasion for the development of some of the very special structures we have studied in land-plants. Root-hairs are not required, neither are the stomata which we have studied in connection with leaves, and which are so important in ordinary plant physiology. Moreover, the nutrition of water-plants is diffused throughout the whole of the medium in which the plant lies—namely, the water—and therefore there is no occasion for any search on the part of the plant for food in the surroundings. It further follows that special organs for such a search are not required. Nearly all water has some form or other of currents in it, or is changed and renewed in different ways, and so keeps up a constant supply which the plant may use. Here, then, we have comparatively simple structures for absorptive purposes in response to the adaptation to the external relations of the plant.



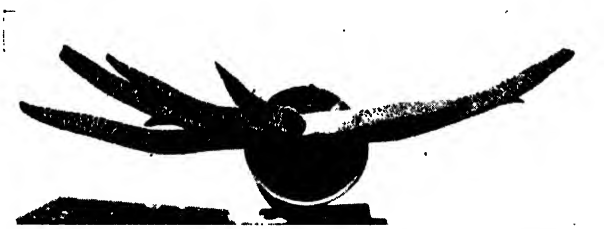
PLANTS THAT GROW IN DARKNESS

In the lower picture are shown mushrooms which grow in a covered stone quarry, the door of which is shown open in the upper picture.

We may next note some adaptive arrangements which have a relationship to climatic, or atmospheric, conditions. For example, it is obvious that some arrangements must be made in plants to protect them from the extremes of cold and heat, and particularly from the rigours of the winter months. Perhaps the most obvious method by which a plant succeeds in surviving a severe winter is that of simply retiring underground for the time being. This is what happens in the bulbs and tubers, which utilise the warm months of the year to store up, by means of their green leaves, enough material to carry them over the winter, and start them growing again in the spring. The more the danger of exposure, the deeper will such bulbs and tubers be found to bury themselves. Thus, those which get some protection from masses of fallen leaves under trees will lie immediately under the

surface, while those in open meadows, with no such protection, retire to proportionately greater depths.

Very interesting is it to note, also, that a strictly analogous proceeding occurs in some of the water-plants, which in lakes and ponds gradually sink deeper and deeper as the cold increases in severity. Thus, the water-soldier, already mentioned, found at the surface during the spring months, takes good care to retire to the bottom of the lake before winter begins, and so passes that period at a depth where freezing never occurs. Other plants retire into the mud at the bottom of pools, and so on.



A SUCCULENT PLANT WHICH GROWS ALL ITS LEAVES IN ONE PLACE FOR PROTECTION FROM THE SUN

In the case of trees and shrubs, which must remain above ground exposed to frost and snow, sufficient food is stored up, as the result of the activity of the green leaves, to carry them on: and these delicate structures are then shed in the autumn, and the parts of the tree left exposed are those which are so covered by Nature as to be able to withstand the severe cold.

As a matter of fact, different species of plants and trees exhibit a very remarkable divergence in their capacity to withstand cold. One might think, *a priori*, that a given temperature would be equally fatal or hostile to all plant protoplasm—in other words, that the same temperature would affect vegetation always in the same way. It is a commonplace of observation, however, that this is by no means the case. Nothing is more familiar than the fact of the difference in the vegetation of different climates. Tropical plants are destroyed even in the moderately severe winters of our own country, while in still colder latitudes the plants which can live outdoors here will perish. So that evidently there is some much more profound problem here than is at once apparent. And, as a matter of fact, the problem is one that no botanist can exactly explain. All that one can say is that whether a plant freezes to death or not in any given circumstances depends upon what we described in a previous chapter as the *constitution of its protoplasm*. In our study of protoplasm itself we paid special attention to that point, indicating that it varied very much in different species; and all that we can say here is that one of the differences in the constitution of the protoplasm of plants confers upon these plants a capacity of resisting frost in varying degrees.

PROTECTIVE CLOTHING OF A PLANT

A succulent plant that shades its leaves and protects them from moisture and animal attacks by spider-web-like hairs

The other extreme of temperature—namely, great heat—is another case in point in connection with which the plant has certain adaptive structures and arrangements that enable it to cope with the difficulty. The result upon a plant of an exposure to too high a temperature is, curiously enough, very similar to that of exposure to too low a temperature. In both cases the green parts of the plant become of a darker colour, fade away, and tend to dry up. When this happens from excessive heat, we say that the plant is burned.

Associated with this obvious change is found also an alteration in the cell protoplasm within. It becomes aggregated into little masses in the cells, and separated from the water, which is extracted by the heat. This change depends upon coagulation of albuminous compounds, the destruction of starch granules, and the ultimate decomposition of protoplasm. Once mo

the special constitution of the protoplasm of the plant is that which enables it to select a tropical area in which to flourish. Some of the other points bearing on this matter have already been discussed in connection with leaves.

There are a few cases which, in their efforts to adapt themselves to their special environment, develop actually a sort of floating apparatus. The water-chestnut is an example of this. Here we find a special modification of the stalk of the leaf, which swells up and acts exactly as a float. The cavity of this buoy is perfectly closed, and is quite different from the sort of growth that one finds, for example, in the pitcher-plant, which contains organs for quite another purpose, as we shall see later on. The object of these floats becomes quite apparent when one examines the leaves which have developed above the level of the water. It is necessary that these should offer as large a surface as possible for exposure to air and light. This end is met by the growth of these floats, by means of which the leaf is enabled to drift about on the surface of the water for its own benefit. In the case of the water-chestnut, which is fixed to the bottom, the leaves are very finely divided, and the swollen leaf-stalk is probably principally of service in supporting the leaves when the rather heavy fruits develop from the flowers.


THE HAIRY GROWTH ON THE LEAF OF SILVER WEED

We may just note in passing the modifications found in plants in connection with the process of transpiration. Plants living in the water, of course, do not transpire, so we do not find in them either vascular bundles or stomata. No matter how big is the sea-wrack—and some of them are huge—they contain no actual wood. Yet these very structures of vascular bundles and stomata and wood are absolutely essential for the life of trees and shrubs. Now, between these two extremes there are endless transitional stages in the degree of moisture of the atmosphere from saturation to almost dryness; and so it becomes necessary for plants to provide some means of promoting transpiration in the one case, and checking it in the other. The former end is obtained by the development on the part of the plant of a large number of cells the surface of which comes in contact with the outer air, these cells being so constructed that they can exhale water. In these cases, too, where it is necessary to facilitate transpiration, there is always a considerable development of green, spongy tissue, which allows of the air to penetrate through the leaf. In a word, it is by the increase of leaf surface that transpiration is principally aided. So we find in water-plants whose stems and stalks are in the water, and whose leaves float on the surface, that the area of the leaf is a very large one. Indeed, the whole surface of a pond may be covered with floating leaves so arranged that the entire upper surface is exposed to sunlight, while the under surface is coloured a violet tint by a pigment, called *anthocyanin*, which has the most remarkable property of transforming the rays of light into rays of heat and thereby warming the leaves.

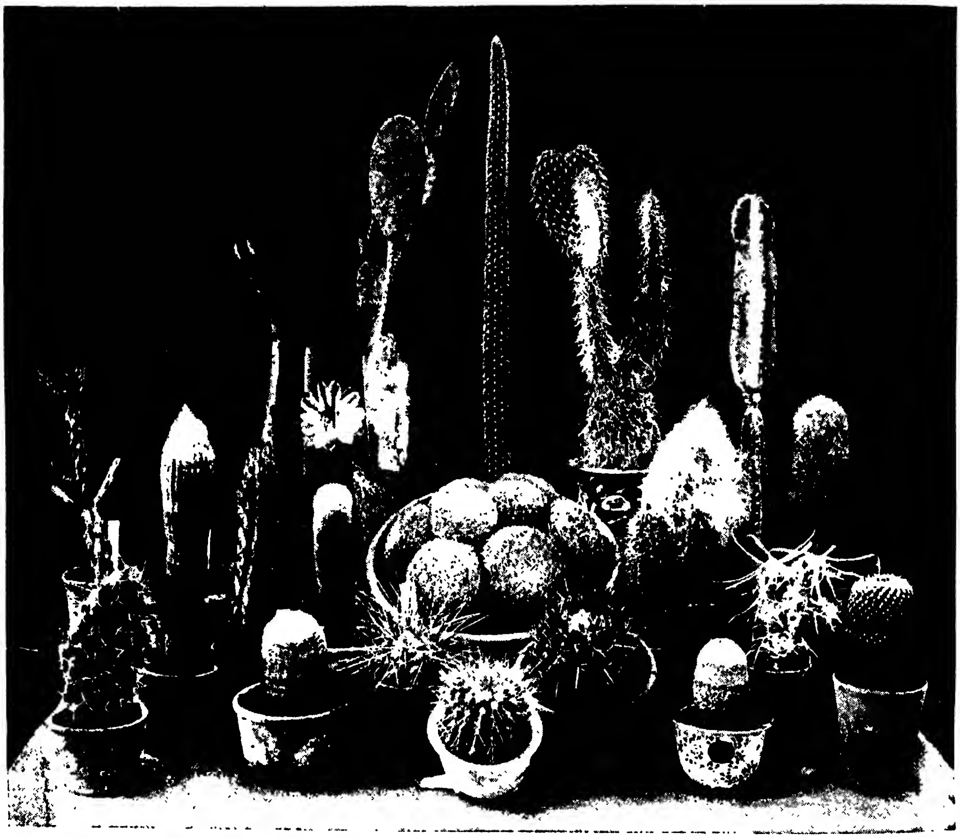
We have referred to the very special conditions of life in the case of water-plants or hydrophytes, and noted some of the

special adaptations made by such plants to accommodate themselves to their peculiar environment. For the sake of contrast, we may turn our attention for a moment to those plants which have to sustain life in precisely opposite conditions, plants which are therefore termed xerophytes.

A xerophyte is a plant which can live even though the water it obtains is of a very small amount. They are drought-loving, or at any rate drought-tolerating, plants. No doubt the first plants in the world were aquatic in their nature and environment, so we must regard the xerophytes as a highly evolved type, exhibiting very special accommodation to circumstances. The conditions under which they live are the most trying conceivable for plants, for they grow in extremely dry soils, in regions rainless during long periods.

Amongst such xerophytic plants we have the yucca, the melon-cactus, and other cactus plants, and the date-palm. These last even the parched and arid desert soil of the Sahara Desert cannot quench, though its moisture comes only from springs.

A true xerophyte, such as a cactus, must transpire very slowly, or it would lose what water it gets too soon; and, moreover, it must have the property of storing up the little water it does obtain. This is the direction in which its special power of adaptation shows itself. The result is seen in the thick, fleshy parts so noticeable in the cacti, the aloes, the stonecrops, and similar plants, structures in which the moisture is carefully stored up for the use of the plant. It is found, too, that the outer skin, or epidermis, of these plants has become extremely thick, and has the power of reviving itself in a wonderful manner, even though it has become dried up. It is not, however, in the leaves only that drought-loving plants exhibit specialisation. In some of them the roots are also adapted for water-storage. More often, perhaps, the stems are peculiarly formed, being of immense thickness in proportion to their



A GROUP OF CACTUS PLANTS THAT ARE SPECIALLY ADAPTED TO HOT AND DRY COUNTRIES

THE GAIETY OF THE OCEAN UNDER-WORLD

THE COLOURING OF SEA-PLANTS, WHICH, THOUGH IT DOES NOT EXTEND TO THE DEPTHS, IS GORGEOUS WITHIN SIGHT OF THE SUN

TO FACE KEY ON PAGE 2489

length when compared with ordinary land plants. These stems contain a large quantity of water. In fact, the plant may be practically nothing but stem, as a cactus is. This obviously reduces the transpiration surface to a minimum.

Even where a xerophyte has well-developed leaves we find they are so arranged as to be exposed to the heat and light as little as possible. The most extreme examples have no leaves at all, but the whole stem is green in its outer part, and does the work usually allotted to the leaf. This is seen in the cactus. The leaves are, in fact, transformed into formidable spines. The formation of all the organic compounds for the plant has therefore to be carried out by the green stem.

THE WATER-CHESTNUT, SHOWING FLOATING APPARATUS

The cactus deserves rather special notice in connection with the study of adaptive arrangements, because it contradicts our usual notions of what the parts of a plant should be like. We generally think of any large plant as having a somewhat brownish stem, carrying a certain number of green leaves. Here we find exactly the reverse. The stem is green, carries no leaves, but instead has a number of brownish or grey spines upon it. The function of the modified leaf, or spine as it now is, is to protect the green stem from injury, this stem being the producer of the organic material we expect to find made by the leaf. Many of these protective spines grow to great length, and are so strong as to make extremely formidable weapons of defence against animals that would otherwise feed upon the green stems of the cactus, as the only green food-stuff in the district.

KEY TO FRONTISPIECE

1, laminaria longicruris; 2, fucus vesiculosus; 3. laminaria digitata; 4, enteromorpha hopkirkii; 5. asperococcus compressus; 6, porphyra laciniata; 7, ulva linza; 8, chara fragilis; 9. polysiphonia urceolata; 10, rhodymenia jubata; 11, nitophyllum hilliae; 12, codium bursa; 13. scinaia furcellata; 14, ulva latissima.

The spines are of very variable shapes and character, and it occasionally happens that the same species of cactus carries upon it spines of different kinds and size. They present a curious and striking appearance, and this possibly has led to the cactus being a favourite plant for cultivation in gardens. If these spines be carefully examined it will be found that the most formidable of them are arranged in such a way as best to protect that portion of the green stem which is the most active, or, in other words, the greenest, portion.

The necessity for such extraordinary protection will be realised if we remember the conditions of the environment of the plant. Imagine the absence of green plant life in the Sahara Desert, where everything has been scorched to a dull brown, or killed outright from lack of rain. The thick cactus alone remains green, and stands out upon the arid plain a brilliant and inviting spectacle for hungry animals. Little wonder is it that Nature has been hard pushed to devise some means to preserve the cactus from extinction under such circumstances, and so we find the formidable spines, associated with the green, leafless stem.

A careful study of the illustration in this chapter of the group of cacti plants will give an excellent impression of the variation in form which they exhibit. Some are almost like balls, others elongated, thick, or fleshy masses; whilst in others the stem is broken up into separate parts or branches, resembling thick-leaved plants. The leaf-like discs of the prickly pear are specially noticeable.

In the preceding paragraphs we have selected a number of widely differing conditions in the presence of any one of which plant life must make some special effort in order to live. We have, however, merely touched the fringe of a very large subject—namely, that of the study of how plants adapt themselves to external relations. What has been said, however, may perhaps serve as an introduction to the general idea of adaptation.

JEWELS FROM A COUNTRY CASKET

GOLDFINCHES

REDPOLLS

WREN

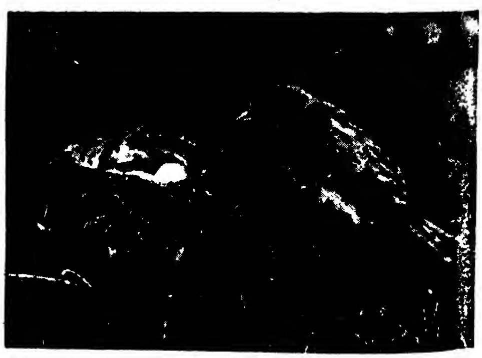
CHAFFINCH FEEDING HER YOUNG

ROBIN

BULLFINCHES

LINNETS

STONECHATS



GREENFINCH AND NEST

These photographs and others on these pages are by C. Reid; and by B. Hanley, Hinkins & Son, W. S. Berridge, and R. B. Lodge.

BIRDS OF INLAND BRITAIN

Familiar Friends in Hedgerow, Garden, Field, and Copse, and their Service to Man

OUR GOODLY HERITAGE OF SONGSTERS

NEXT to the mammals in the scale of creation come the birds. They represent a superb triumph for evolution. They, with the bats, are the only vertebrates that fly; the so-called flying mammals do not, except in the case of the bat, attain true flight, as has been already noted. Yet the bird is simply a transformed and glorified reptile. It preserves many reptilian features. The scales upon the leg are reptilian vestiges, the beak recalls the reptile, the production of the young from eggs is reptilian; and there are structural features of all birds which point unmistakably to a reptilian ancestry.

From what reptile, or group of reptiles, the birds are derived cannot yet be stated. Records in the rocks, while wonderful enough, do not carry us back to the starting-point. We can trace birds to toothed ancestors, and we can find winged reptiles with many bird-like characteristics. But the gaps are serious, and we can point to no earlier true bird form than the archæopteryx, marvellously preserved in the lithographic stone of Bavaria.

If there were any doubt as to the hands of the reptiles having become the wings of birds, the archæopteryx would remove it, for there, clearly indicated in its remains, are three unmistakable clawed fingers. This ancient bird had teeth in both jaws; it had a long, fleshy, lizard-like tail, with two quill feathers to each of the twenty caudal vertebræ. The arrangement of feathers which we now call the tail of the bird is a modern improvement that had not been evolved when the archæopteryx winged its way from tree to tree in the primeval waste. Ancient as is this bird, we know that it was not the first type of bird; it was far too specialised, primitive as were many of its characters. But we cannot as yet get behind it; rocks must crumble and seas turn back from deposits long covered before we know the full story.

It must suffice for the present that the bird *is* descended from a reptile; that from cold-blooded ancestors it has become the hottest-blooded of all living creatures—with a temperature of 112 degrees in some cases; that it has evolved a unique form of insulation in its feathers; bones remarkable for their lightness and their inclusion of air-spaces, like the air-spaces which the hollow tubes of a bicycle frame contain, and answering precisely the same purpose; that it retains the nictitating membrane of the eye which the reptile has, and of which the vestige remains visible in the eye of man; that in place of the hideous bellowings of the crocodile it has become possessor of a multitude of vocal methods, from the scream of the eagle, the gobble of the turkey, and the crowing of the cock, to the quintessence of melody in the rapturous song of the nightingale. It has developed, in the beak, perhaps the most wonderful organ in the world next to the hand of man—an organ with which it secures its food, whether living prey or the seeds of a nettle; an organ with which it builds almost incomparable dwellings—dwellings of masonry, woven dwellings, sewn dwellings; an organ that serves for battle and defence, and for the purpose of feeding its young. Decidedly, the beak of a bird is, next to the hand of man, the most wonderful natural implement yet evolved.

There are at least fifteen thousand recognised species of living birds, and many extinct forms have been traced, the latter mainly ancient, but some quite modern. No two naturalists quite agree as to classification. There is less difference structurally between an ostrich and a humming-bird than between a lizard and a crocodile. Huxley proposed a name which described

MISSEL-THRUSH

the whole bird kingdom as "lizard-like animals." Today some naturalists suggest a classification which divides the whole assemblage into two groups—the birds which fly and the birds which do not; and subdivides these into twenty, thirty, or more orders. Many portly volumes are required adequately to deal with the subject, and it is quite impossible within the limits of the present work to attempt anything in the nature of a complete survey. It can only be hoped to include such characteristic examples as shall stimulate the interest of beginners in the study of Nature, and induce them to extend their investigation to books devoted solely to this fascinating subject.

WRYNECK

WHINCHAT

In beginning with the birds which we call British we can but indicate a selection, for, much as we deplore the diminishing number of native birds or regular visitors to Great Britain, it is a fact that there are very few orders of birds not represented here, either as migrants or settled inhabitants. The importance of bird life in Great Britain, from an economic standpoint, altogether apart from æsthetic considerations, has been suggested in an earlier chapter. Here we shall consider characteristics of a few types. No bird can more fitly introduce its fellows than the nightingale, which, although it winters in Africa, is born on British soil. Here it may be of interest to note that migratory birds nest and rear their young in the summer of the colder of the two lands to which they resort. The nightingale arrives in April and departs in August or September, and rears one brood, occasionally two. The male is decidedly robin-like in form and gait, though its colouring is more sober, the under parts being greyish white in place of the ruddy breast of the robin. The birds nest beneath hedge or thicket, and are entirely insectivorous for the early part of their stay, though they will eat berries later. Nothing new can be added to what has already been written of the song of this bird. Mr. Hudson, an admirable writer upon birds, believes that the nightingale has been overpraised. The criticisms which he has recorded, however, certainly proceed to the opposite extreme. It should always be remembered that there is a great difference between the song of one nightingale and another. The aviarist who knows that one canary sings better than another canary possibly does not look for such gradations in wild birds; but there is just as great a difference. Much depends, too, whether the bird be heard by day or night. Even by day there is a distinctive glory about the nightingale's notes which no other bird possesses, but it is at night, when all the world is still, that the full splendour of his song is best heard. Kubelik playing in an orchestra is still Kubelik, but he cannot be so well heard; and the nightingale singing in the full chorus of adjacent birds contributes but one of many items of melody. Most of us prefer the nightingale of Keats's ode to the nightingale of Mr. Hudson's judgment.

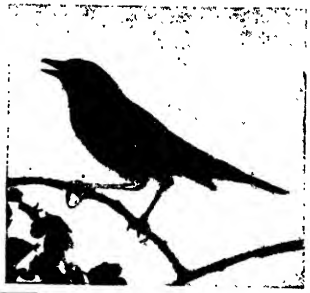
WHITETHROAT

The song-thrush and blackbird have notes which startlingly resemble the nightingale's, but the little canary bird, with the long-drawn, plaintive, ascending succession of wailing notes, approximates most nearly to the king of songsters. We cannot claim this little golden songster as truly British, for his home is in the islands from which he takes his name; but he has been so long domesticated here, as in other European countries, that certain varieties, notably the Norwich and the Yorkshire, may be considered natives. The wonderful song and the

LARK

delightful colouring are the results of careful breeding, for in a state of nature the canary has a limited number of notes, and his colour more resembles that of the charming little yellow singing finch of West Africa, with which every aviarist is familiar, than that of his golden yellow cousin in an English cage.

The robin, a near relative of the nightingale, is probably second favourite; indeed, he may rank first, generally speaking, for, whereas the great singer is limited in his range, the robin goes wherever a human habitation is to be found – in country garden, and in the apologies for gardens in the mean streets of cities. Redbreast is the central figure of many a pretty legend, and popular belief, not without some foundation, associates him, with the dog, as among the earliest friends of cave-dwelling man. His fearless habit of entering human dwellings is believed to date from times in which he was able to flit in and out of the windowless abodes of our prehistoric ancestors.



NIGHTINGALE

FIELDFARE

A preposterous tale has it that the robin murders its offspring or is done to death by them. The fact is, of course, that in the struggle for existence the robin family must disperse, or all would starve. The quarrels between adult offspring and their parents are not peculiar to robins. Who that has kept the gentle dove and the amiable pigeon needs information upon this score? How long will the cock pigeon tolerate his young ones near his nest after the first month when he has laboured to feed them? Stories of the pugnacity of robins are apt to be overdrawn. One has seen an English specimen shamefully bullied out of his food by a hen sparrow, and one of the so-called "Pekins" absolutely routed by a waxbill of about the size of a humble-bee. The blackcap is another of our famous songsters, ranked by Gilbert White and not a few other observers as second only to the nightingale. Though it ranges throughout the entire United Kingdom, it is nowhere numerous, and there are probably as many people who have not seen a blackcap as have failed to come to close quarters with the nightingale. The charming whitethroat belongs to the same group of birds as the warbler, and spends the same part of the year with us. Mainly insectivorous, it is of great service in the early summer when constantly carrying food to its young.

KING-FISHER

JAY

Like the courageous nightingale, the whitethroat clings to its nest in face of danger. One whose nest was approached this year hopped a few branches away what time two of its eggs were abstracted and two from an aviary substituted. No sooner was the intruding hand withdrawn than the bird had settled down on her nest again with the most engaging confidence. Though visited repeatedly during the period of incubation, she brought off her young ones with never a suggestion of deserting her nest. Ten yards away from her a greenfinch reared her young under as close observation, yet in another part of the same garden a second greenfinch deserted a clutch of eggs upon experiencing one fright.

PIED WAGTAIL

It is difficult to lay down any hard-and-fast line as to how birds of even the best-known species will behave under similar circumstances, and many a general statement based upon insufficient observation becomes accepted as an immutable law. One ordinarily dependable authority lays it down as a fact that the greenfinch will never eat insects, and the results of such observations as have been made under

Board of Trade auspices lend some support to this view. But personal experience shows that these birds will and do eat insects in a large open-air aviary where there is abundance of the food that they like. It is a greenfinch which first attacks greenfly upon slips of ivy provided for the true insect-eaters. But that the greenfinch is an enemy to seed crops cannot, unfortunately, be denied. Happily, he is such a favourite with bird-lovers that he is in no great peril from repressive methods.

The greenfinch is a model bird compared with the ubiquitous sparrow, which is now becoming a serious menace to farmers. We have not a more mischievous bird in the land. We have practically exterminated the bulk of his natural enemies, and it is possible that he outnumbers all the rest of our resident birds put together. He is a great grain-eater; he delights to demolish flowers, and, apparently out of sheer wantonness, to peck off and discard fruit-blossoms. The writer examined a treasured plum-tree which had not borne fruit for some years. It was covered at last with blossom, and one heart that day rejoiced. A couple of hours later that tree had hardly a blossom left; the ground below was white with them. A chattering chorus of sparrows had nipped them all off, and were still at their fell work when their one-time champion returned. That incident, unfortunately, is typical of what happens in many a garden.

A GROUP OF YOUNG MAGPIES

Sparrow clubs are the order of the day, but the grievous thing is that their members, if they aim at sparrows, bring down such an astonishing number of larks and wagtails and flycatchers and other desirable birds. If every member of a sparrow club had to pass an examination to prove that he could identify a sparrow on the wing, and that he had no desire merely to kill any bird which he might choose to call a sparrow, these clubs might justify their existence. But members of the Royal Society for the Protection of Birds are not alone in their distrust of these bodies.

One unhappy result of the excessive multiplication of sparrows in our midst is a corresponding decline in the number of house-martins. The sparrow is a snapper-up of other birds' nests, notably those of the house-martin, a bird the sparrow, by his superior strength, is able to oust. Year by year the numbers of these charming birds are diminishing, and sparrows, though not necessarily the main cause, are clearly contributories. The same regrettable fact is noted in regard to the swallow, between whom and the martin not everybody readily distinguishes. Both build charming little cup-shaped nests of mud and hair in the shelter of barns and out-buildings, or under the eaves of houses, and both prefer the dwellings of man to all other sites. The swallow is brown upon forehead and chest, the martin black; the swallow has the lower parts dull reddish-white, the martin pure white. In the swallow the size of the wings and tail exceeds that of the martin. The swallow has the legs and feet smooth, the martin's being feathered. Both birds, like the sand-martin and the fast-speeding swift, are purely insectivorous, and feed upon the wing, except at such time as the female is brooding her eggs, when she receives her food from the male.

All the members of this group are notable fliers, the swift being by far the most brilliant performer in the air seen in Britain. Curiously, these birds, like certain of the powerful birds of prey, cannot easily mount into the air from the ground; they have to launch themselves into the air from a height. Hence their nests are placed at a higher level than the point of exit. Once in the air, however, their flying powers are incomparable. Many examples of their proficiency have been given, but one which came under the writer's personal observation seems worthy of record. A motor-car was travelling at a pace which it would be inconvenient to discuss with the police. A swift overtook and passed it, plunged down directly in front of the speeding car, caught

an insect, rose straight into the air again, all within what seemed but the fraction of a second.

Needless to say, the swallow tribe has many foreign representatives, some of which penetrate the Arctic Circle. The swallows and swifts, though popularly grouped together, are divided in scientific classification and associated, the former with the flycatchers, and the swifts with the humming-birds and nightjars. We lack the humming-bird, but are happy in the possession of the nightjar during the summer months. Like the owl, it is noiseless in flight, so far as the action of the wings is concerned, though the curious cry from which the bird takes its name might wake a sound sleeper in his bed. This bird frequents open, uncultivated land, as well as woods, and returns year after year, with unerring instinct, to the same unmarked spot. It makes no nest, but lays its eggs upon the bare ground. The same fidelity to a locality is shown by the spotted fly-catcher, which, arriving in May and departing in August, makes its nest again and again in the same cluster of ivy, or in the same hole in wall or tree, and day by day takes its station upon the same post or stump or branch, sitting mute and motionless until a fly heaves in sight, when the little huntsman launches itself into the air, captures its prey with an audible snap of the beak, and returns to its dull vigil. The pied flycatcher arrives earlier than its spotted congener, and is, unfortunately, more rare, for its handsome black-and-white plumage makes it a desirable addition to orchard or garden. But its economic rather than its æsthetic value is chiefly considered.

Every insect-eating bird is worth a very great deal to us. The tits have a similar appeal. All these birds—titmouse, bearded titmouse, coal-tit, long-tailed great tit, crested tit, blue tit, and marsh-tit—are allies of the agriculturist and gardener, for though, when fruit in the orchard ripens, they may take a slight toll of the produce which they have involuntarily helped to guard, in the spring and early summer, when insects are most destructive, they search every leaf of every tree upon their beat, taking not only the adult insect, but larvæ and eggs as well.

A bird similarly helpful is the nuthatch, which, though its food during autumn consists of hazel nuts, seeds of the yew and Portugal laurel, lives in the spring and summer exclusively upon insects and their larvæ. These charming birds nest in holes in trees, cleverly fortified by clay. They can be tamed easily by placing nuts and other food near a house in whose vicinity they live.

The wren, though so tiny a bird, is a prodigious collector of caterpillars and other injurious insects. These, from dawn till dusk, it carries to its young in the most perfect of little domed nests, placed in any situation that may suit its fancy. This, with the golden-crested wren, which is not related to the other species, except in point of size, is our smallest British bird, and one of the most independent.

A GROUP OF YOUNG CHIFF-CHAFFS

The tree-creeper, as its habits suggest, is an inveterate enemy of harmful insect life, and as it takes a turn pretty frequently in the wake of cattle, it is believed that some of the pests by which these animals are tormented fall victims to this alert little bird. There is not yet, however, more than presumptive evidence on this point. The feeding habits of the wagtails resemble those of the tree-creepers in respect of their attendance upon cattle, but, instead of trees, the lawn and the open pasture are the hunting-grounds of the pied species, the neighbourhood of mountain streams that of the yellow-grey wagtail, and the track of the plough and the path of far-roaming cattle that of the yellow variety. The first-mentioned, though the least pretty, is the best known, because of its fearless association with the haunts and homes of man.

The woodpeckers—great spotted, lesser spotted, and green—are indefatigable allies

of the forester and gardener. All are tree-borers for the purpose of their nest, and borers in quest of food. In any well-wooded land of the parts of the country which they inhabit, the urgent tapping of their sharp bills may be heard as they drill into the wood or tear off the bark beneath which some wood-boring grub or the larvæ of injurious moth is concealed. Given fair promise of success, they will overhaul a woodstack close to the home, and leave barely a larva behind. Woodpeckers heartily relish ants, and in winter visit the hills of these little creatures with almost as much success as attends the efforts of the aardvark in a warmer clime. The same nest will serve a green woodpecker year after year, unless, in the absence of the owners, a couple of acquisitive starlings take possession.

The wonderful metallic sheen of these handsome British residents, their curious costermonger strut, their extraordinarily varied notes, and their untiring activity in the vicinity of human dwellings make them as well known as the sparrow. They flourish perhaps over-abundantly in Great Britain, and undoubtedly do damage to fruit crops in the late summer. But their services in the earlier part of the year are inestimable. At that time they are almost exclusively insectivorous, and among the most potent "insecticides" that the farmer possesses. They assemble in such vast throngs upon ploughed land that, when they start up affrighted, it seems for a moment as if the entire surface of the field is being suddenly raised. Here they consume myriads of grubs and larvæ of the daddy-longlegs, a most destructive pest.

Next in numbers to the starlings come the members of the thrush tribe. They have, in the blackbird and the throstle, or song-thrush, two of the finest of English songsters. The missel-thrush, or storm-cock is the gallant bird which pours forth its rich melody when the days of spring are stormiest. The song-thrush, too, is hardy and widely distributed over the land, and in winter-time is thoroughly at home on the seashore, where it makes a comfortable living on molluscs. The redwing, a very handsome thrush, comes to us from Northern Europe for the winter, its flight coinciding pretty much with that of the fieldfares, which flock over in myriads from the colder parts of Northern Europe, where a living is impossible in a frostbound land.

A HEDGE-SPARROW ON HER NEST

Blackbirds, which with the ring-ouzels form a sub-genus, are among our indigenous birds, though we receive additions for the winter. Even those that stay all the year round appear to shift their quarters, the trend being northward in the summer, southward as winter returns. All these birds build cup-shaped nests, and the birds themselves are strikingly similar in habit. Worms, slugs, and snails are their chief items of diet, though little that is eatable comes amiss to them. They are all regarded by farmers as enemies. They are undoubtedly very destructive in strawberry-fields and orchards. Cherries suffer particularly, and in their determination to have this form of fruit the birds show some ingenuity. A man who saw his cherry crop disappearing down the throats of multitudinous thrushes and blackbirds bought himself a gun, and blazed away with blank cartridges. For a short time the alarum acted like a charm. But then the farmer noticed that the birds, instead of flying away as they had at first done, merely dropped down into the long grass at the foot of the trees. And he discovered that each bird took a cherry with it as it dropped! The birds had learned that, alarming as the bark of the gun might be, it had no bite.

The wheatears come between the thrushes and the robins, and with the chats constitute a sub-family. The first-named winter in Africa, and traverse the entire breadth of Europe, to reach Great Britain in the early spring, and help to keep our insect population in check. Both this bird and the whinchat, another summer visitor, sit, like small sentinels, awaiting the coming of an insect. Then they dart out from their place of observation, strike unerringly, and return with a little note of triumph to their former position. The stonechats do not all leave us in winter, many of them merely migrating to the warmer corners of our own land, while the remainder seek the Sunny South afar.

So far a few of the songsters of our land have been named, but there are many more, such as the lark and the finches, which claim a place in any musical company. The sky lark inspired Shelley as the nightingale inspired Keats, and has an unassailable place in our literature, as it has in the affections of every bird-lover. It is singular that the bird which " sings at heaven's gates " should nest upon the ground and be distinguished above all others for its love of a dust-bath. Mainly insectivorous, the lark will eat seeds and the tender herbage.

It is difficult to write temperately of the cruel treatment of this bird, one of the chief glories of the feathered world. Those

A ROOK ON HER NEST

How these migrations are accomplished we do not know. How a nightingale finds its way from Africa to the very bush in England upon which it nested in the preceding year, the swift to the same little mud nest, the nightjar to the same depression in the soil of the same wood or open plain, is a mystery which we can explain only by saying that birds, like certain quadrupeds, have a "sense of direction"; that sense which brings a homing pigeon safely over the sea to its loft directs the crab seventy and eighty miles back to the old feeding-ground from which it has been artificially removed, and guides the sightless limpet from its rambles in search of food at low tide back to the identical niche which it has cut for itself in the rock.

that are maintained in captivity are frequently kept in barbarously small cages, lest the bird in its passion for soaring aloft should dash its poor head against the roof of its cruel prison. But the majority of those captured are for the table of unspeakable gourmets who, with a morbid passion for a form of food against which conscience rebels—such as distinguished the eaters of nightingale's tongues—encourage the slaying of these delightful creatures by scores of thousands every year. There is no space for even casual mention of the abominations practised at the cost of our British birds, but we must hope that some day our Parliament will legislate as freely for our song birds and beauty birds as for the birds preserved to be shot. Tastes differ as to the song of birds,

but all must agree to award a very high place to the goldfinch, a good specimen being a serious rival to a canary of exalted lineage, while its plumage is rich enough for the tropics. The chaffinch, one of the most perfect pictures of bird beauty, and one of the finest nest-builders, is also highly to be admired, though master of a less varied strain than the goldfinch. This bird is the victim of an atrocious practice. Singing matches—" bird races," as they are called —are held in low public-houses with chaffinches as competitors. The birds are blinded by the use of a red-hot wire in preparation for these infamous competitions; and, though our R.S.P.C.A. seeks vigilantly to stop the hideous practice, the wagering and drinking around the tortured birds still take place.

The bullfinch has a sweet pipe, but is not naturally a songster. He is, however, one of the most educable of birds, and, if taken in hand when young, can be taught to pipe a number of tunes. The present writer saw one exhibited for sale the other day—a poor, bedraggled creature, without a clean feather upon it. But it could whistle two short tunes, and its price was £4! The linnet is another delightful little songster, with certain rich, broad notes which reproduce in tone and volume, though not in sequence, the lusty little song of the red-crested cardinal. The linnet's small relatives, the lesser redpolls, closely resemble these birds in plumage, though clearly distinguishable by the ruddy crown and the smaller size. The redpolls have a merry little song, too, and make delightfully active, contented inmates of a good outdoor aviary, in which a linnet sings his best the livelong day.

There are a host of other birds beautiful as the yellow bunting (or yellow-hammer) and the redstart, the siskin and the brambling, sweet-voiced as the Dartford warbler; but to include them all would take in the greater part of the bird world. Who needs to be reminded of the cuckoo, with its strange parasitic habit? There seems something unspeakably barbarous in the extinction of every other nestling in the cuckoo's stolen cradle. Yet what is it but the story in essence of the struggle for existence condensed into one brief tragic act before our eyes? Wordsworth, who was a better naturalist than most of us, dedicated one of his most ecstatic odes to this " Thrice welcome darling of the spring," and we must be thankful that our favourite perpetuates its species by no more barbarous means. Better a stolen cradle than little birds speared alive upon a thorn, as is the case when the red-backed shrike lays up provision for a meal-to-be.

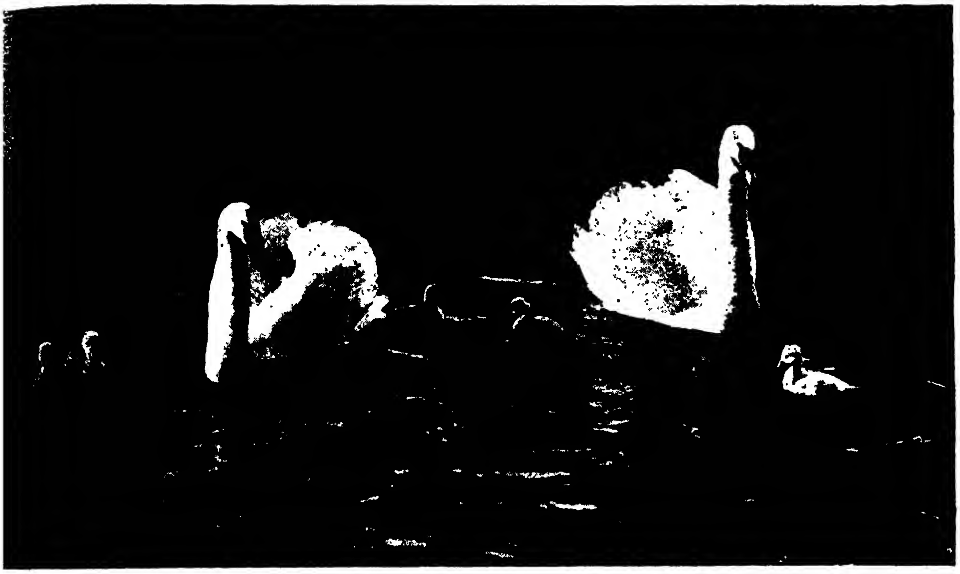
LONG-EARED OWL

WHITE OWL

TAWNY OWL

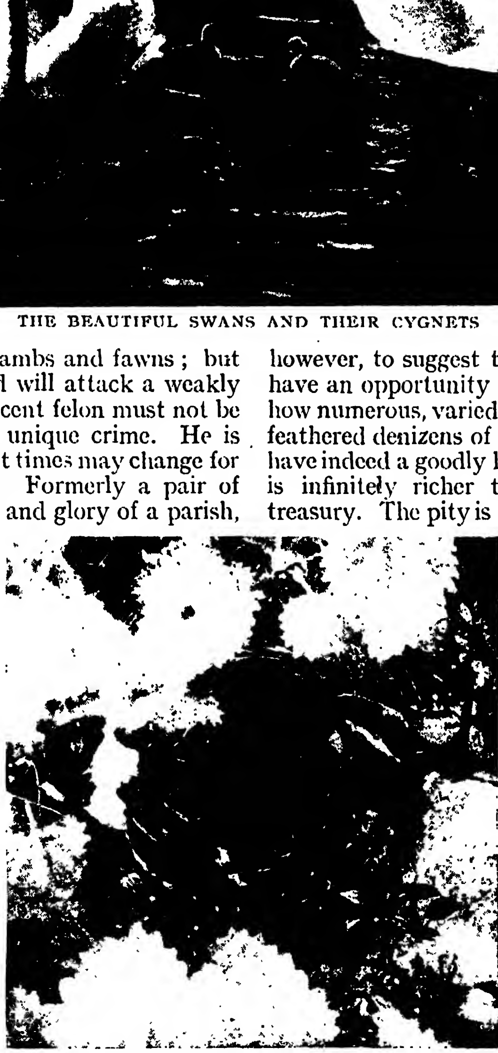
Birds of prey, such as the eagle and hawk, must be treated later, but we ought here to notice our owls, of which we have four species, despite all that the selfish game-preservers can do towards exterminating them. These species are the barn or white owl, the long-eared, the short-eared, and the tawny owls, silent messengers of destruction during the night, when mice, rats, and voles are abroad and man asleep.

The crow tribe merits a chapter to itself, for, although the group contains some of the birds most destructive of other forms of life, it is here that we find bird-brains at their brightest. The carrion crow and the hooded crow both have bad names as snappers-up of young game and small birds; but their numbers, especially of the hooded species, are very small. Ravens undoubtedly do damage on isolated sheep and deer runs by attacking the eyes



THE BEAUTIFUL SWANS AND THEIR CYGNETS

of young and feeble lambs and fawns; but almost any other bird will attack a weakly fellow, so this magnificent felon must not be adjudged guilty of a unique crime. He is out of fashion now, but times may change for him as for the rook. Formerly a pair of ravens were the pride and glory of a parish, while the rook was proscribed by a law of Henry VIII. To-day, in spite of all that farmers may say against the rook, a rookery is a sovereign addition to the country house. War is being waged anew on the rook, but its greatest enemies are those who have studied its habits least. When the man with the gun has had his way, and leather-jackets and kindred pests hold high revel in our fields, we shall, too late, admit the value to agriculture of this grand bird. The same meed of praise, though to a less extent, may be awarded the jackdaw and magpie, two of the wisest birds in creation.



WILD DUCK, OR MALLARD

We must leave the water birds for later consideration, and all too many others have to be omitted entirely. Enough has been said, however, to suggest to those who may not have an opportunity of noting at first-hand how numerous, varied, and attractive are the feathered denizens of the British Isles. We have indeed a goodly heritage; our avifauna is infinitely richer than our mammalian treasury. The pity is that familiarity breeds contempt, that we pass the countryside unheeding the beauty of plumage, the glory of song, which greet us on every hand. We take our birds too much as a matter of course.

What a birdless Britain would be we sometimes realise upon entering a wood in which heartless youth has had its way, and not a bird can find safe nesting. The silence is most melancholy; the absence of birds makes the wood seem a place of death. When upon the solitude breaks the twofold shout of a distant cuckoo—jovial and sweet—we feel disposed to cry aloud to him, with Wordsworth, as he dispels the depressing silence:

> O blessed bird! the earth we pace
>   Again appears to be
> An unsubstantial, faery place:
>   That is fit home for thee!

THE TRAVELS OF SOUND IN THE EAR

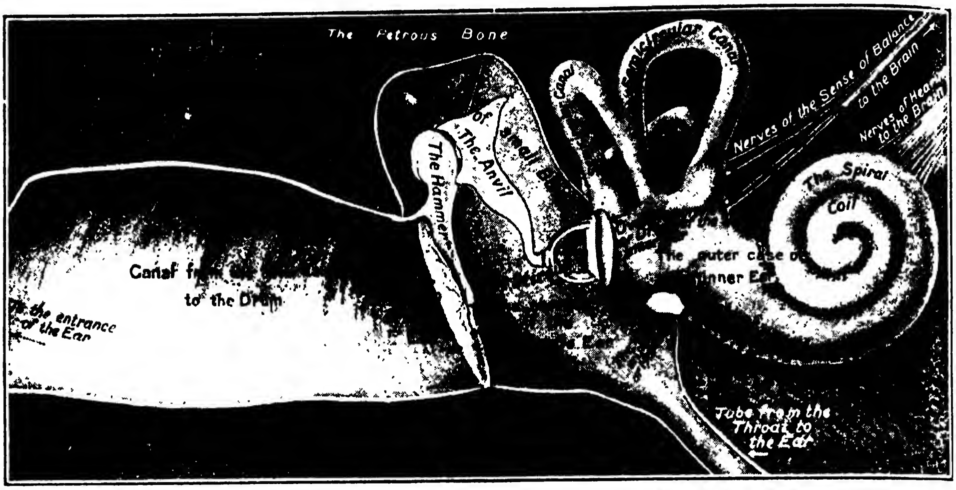
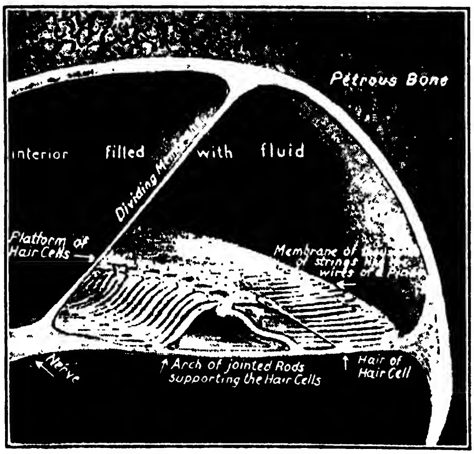
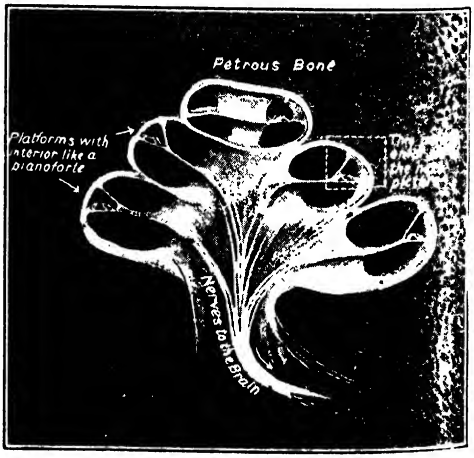


DIAGRAM OF THE CHAMBERS AND BONES OF THE OUTER, MIDDLE, AND INNER EAR

DIAGRAM SHOWING THE PASSAGE OF A SOUND-WAVE FROM THE OUTER AIR TO THE AUDITORY NERVE



SECTION OF THE COCHLEA, SHOWING THE INTERNAL DISTRIBUTION OF THE NERVES



ENLARGED SECTION OF PART OF THE COCHLEA, WITH THE RECEPTIVE NERVES IN DETAIL

THE WONDERS OF THE EAR

The Marvellous Adjustments of the Ear for its Multitudinous and Delicate Uses

DO WE THINK THROUGH SIGHT OR HEARING?

On every ground we are justified in dividing the senses into higher and lower, and there is no doubt that vision and hearing stand together, with never a third, in the first category. They are higher because they are of later evolution. Probably all the qualities of sensation have been slowly evolved, in the immeasurable past, from some primitive obscure quality of sensation more of the nature of touch or pressure sensation, or perhaps from two qualities, one aroused by pressure and the other by chemical agents—this latter being the ancestor of modern taste and smell. Hence touch, taste, and smell as we have them are historically more primitive in type than vision and hearing.

The question, like all questions in this realm of psychology, is of some æsthetic and ethical importance, for the claim is sometimes made that all the senses are necessarily of equal rank, and that therefore the pleasure of the palate, for instance, by the art of cooking, or the cultivation of the olfactory sense in certain decadent individuals, must be reckoned as on a par with the pleasures of painting and music.

To this the reply is that, historically considered, the senses are not equal. Nor are they equal when considered from the standpoint of their capacities. We must regard as higher those senses which have a great variety of possible qualities, and which afford us the largest measure of information about the external world, or of communication with our fellows. Thus judged, sight and hearing are obviously far higher than, say, the temperature sense, which has a very small variety of qualities, and affords us a very limited range of information.

Nevertheless, there is no doubt as to the very simple beginnings of the highest senses. Vision, with its infinite perceptive and creative possibilities, begins in simple sensibility to light, such as we find in many of the lowest forms of life. But living organisms have made incalculable use of this primitive capacity, until, in the highest animals and in ourselves, they have developed, as we have seen, special structures which not merely appreciate light, but can distinguish between the qualities of light of all colours. This subtle discrimination of colour, achieved by means of the recently developed cones of the human retina, marks the level to which the primitive sense of light has attained.

There is here a close parallel with the ear and the sense of hearing. Historically, and even to-day, that may be called a pressure-sense. The physicists tell us that sound is simply a series of to-and-fro waves in the air, or some other medium, which reiteratedly bang away at the drums of the ears. It is essentially a series of taps, and nothing more. Vibrations made by a very large and heavy tuning-fork will excite waves in the air that may be just too infrequent to be heard, but are readily felt by the skin, and such an observation shows us at once the simple physical and psychological relation between the touch or pressure-sense, and hearing. Doubtless this pressure-sense must be as primitive and as early developed in the history of life as sensibility to light; indeed, the very earliest forms of life, developed in darkness, must have been sensitive to pressure.

But modern hearing is entitled to be called one of the higher senses, as compared with the primitive pressure-sense which is still illustrated in the surface of the skin, because of the great range of qualities and great powers of discrimination between them which this sense now exhibits. Apparently there is a close parallel between its recent development, culminating in man,

and that of vision. Colour in light corresponds to pitch in sound. In each case the scale depends upon the frequency of the respective waves. When the eye distinguishes colours it distinguishes wave-frequencies, and exactly the same is true of the ear when it distinguishes sounds. We have seen that the modern eye is marked by its capacity to distinguish colours, and that this depends upon the development of a comparatively recent structure, the cones of the retina. Just so do we find that the appreciation of pitch, upon which the possibility of music, to name nothing less, depends, is a recent development of the sense of hearing, and appears to depend upon the most recent structure in the ear, which is known as the organ of Corti, and is thus the aural parallel to the cones of the retina.

But in the case of the eye we did not reach the cones of the retina until we had traversed a very complicated apparatus for conduction and control of the waves of light. Similarly, before we reach the organ of Corti in the internal ear, we have to study a sound gathering and conducting apparatus. The ear has no lens by which the sound-waves can be focussed just like light-waves, but it has an apparatus for gathering sound-waves, which comes to much the same thing, and it also has muscular arrangements for controlling the intensity of sound, corresponding to the iris of the eye.

What the Ear has Lost and Gained During Its Evolution

What we commonly call the ear is simply a gathering device, markedly decadent in man, which can no longer be controlled by him either for the better reception of sound or for the detection of its direction. It is true that the external ear is provided with three small muscles, but only a few people have voluntary control of them, and even those persons do not put them to any use. The reflex mechanism which would enable us to "cock" our ears has also fallen into desuetude. This is merely one more of the many instances in which the body of man is decadent, and if we test his hearing quantitatively we may be tempted to regard this sense as inferior in him, compared with many of the lower animals. But, judged by what we have declared to be the only legitimate test, which is qualitative, the human ear is quite incomparable.

The external ear is not entirely negligible, however, for if it be experimentally filled with wax, except for an aperture corresponding to the canal which leads inwards from it, the hearing is somewhat dulled. But if we desire to estimate the direction of sound, we have no machinery now for the purpose, and can only compare the relative intensity of the sensations set up in the two ears. Long and careful experiment by Lord Rayleigh has shown that this alone is accountable for our appreciation of the direction of sound. It follows that we cannot distinguish between sounds made at the back of the neck or under the chin, if these be produced when we are blindfolded, for sound coming from such positions is equally well heard in both ears, and we are left without guidance.

The Drum of the Ear a Genuine and Designed Drum

From the external ear a canal leads inwards until it is closed by a definite and unmistakable drum-head. The canal is lined with glands of a peculiar type, which secrete the wax of the ear, in order to keep the canal clean. The drum of the ear, or tympanum, is no more figuratively so named than the lens of the eye. It is what it is named, and those who can credit its origin by the natural selection of chance variations can credit anything. If this drum be looked at by the aid of a beam of light thrown into the auditory canal, a deep shadow is seen to be lying across it. This is due to the first of a chain of three minute bones, the auditory ossicles, which are found in the middle ear. From their form these three bones are called the malleus, incus, and stapes—the hammer, the anvil, and the stirrup respectively; and they are jointed together as the diagram shows, so that they communicate between the outer wall of the middle ear, constituted by the tympanum, and its inner wall, which has a window, or opening, also closed by a membranous drum, to which the foot of the stirrup is attached.

The Special Dangers of the Air-Filled Middle Ear

The middle ear is filled with air, a very remarkable fact, which has serious bearings. The air requires to be supplied to it, for its oxygen is absorbed by the blood in the neighbourhood, and carbonic acid is given out, by a process of very subsidiary breathing, comparable to what we have seen in the lungs. Also the pressure of the air in the middle ear must always be the same as the pressure in the auditory canal, so that the drum of the ear, having equal pressure on both sides of it, can vibrate freely when sound-waves strike it. Hence a special tube runs from the back of the nose to the middle ear on each side, and supplies it with air.

This is a physiological necessity, but it is

also a source of danger. It means a route of infection from the nose and throat. Thus microbes that have obtained a hold there, as in scarlet fever or measles, are very liable to travel up this Eustachian tube, as it is called, and to infect the middle ear. Short of that, inflammation of the throat is apt to close the Eustachian tubes, and so interfere with hearing, as we know in the case of a common cold. But actual middle-ear disease is a serious affair. It is very apt to lead to the perforation of the drum, an irreparable disaster, and it may involve the thin bony roof of the middle ear, upon which lies part of the brain itself. Hence the Eustachian tube is the route by which an infection of the throat may lead to inflammation of the lining of the brain, technically called meningitis, or to abscess in the brain itself. The practical moral of this is to enforce far more attention than most people now pay to the hygiene of the nose and throat, especially in children; and meanwhile eight per cent. of the nation's school children have adenoids.

Air, Bone, and Fluid each Used in the Ear as a Conductor of Sound

Inside the middle ear we find two muscles, one attached to the malleus, and called the tensor tympani; the other attached to the stapes, and called the stapedius. When the former is thrown into contraction it pulls upon the malleus, which is attached to the tympanum, so that the tympanum is tightened and made considerably more responsive to sound-waves striking it. This is the muscle which we throw into action when we strain to hear.

Not less important is the action of the stapedius, which is to damp down the vibrations of the bony chain, so that loud sounds are made less intense. One of the reasons why expected noises are so much less distressing, and why people cheerfully bang the door who resent other people's carelessness, is that the stapedius muscles in the two ears are thrown into anticipatory action. In certain injuries to the facial nerve, which sends a slip to the stapedius, this muscle is paralysed, and then loud, sounds are apt to be very painful—like a bright light thrown into eyes of which the iris has been paralysed by belladonna or its active principle, the alkaloid atropine.

Apparently these arrangements for the control of sound furnish the chief or only reason for the existence of the middle ear. There is no doubt that the chain of bones through which these muscles act are the efficient conducting arrangement, for hearing is markedly impaired if the bones be destroyed by middle-ear disease, or even if the tiny, delicate joints between them be stiffened in old age.

The sound-waves passed through air in the auditory canal, through a chain of bones in the middle air, and now they come to fluid, and are conducted in it, so that we actually hear sound-waves in water, like our remote fish ancestors when the ear was first being evolved. This fluid is contained in the inner ear, which is closed by the membrane to which the foot of the stapes is attached.

The Firm Bony Protection of the Ear's Delicacy

The whole of this apparatus lies buried inside the hardest bone in the body, which is accordingly named the rocky, or petrous part of the temporal bone. The hardness of the bone is probably an advantage from the point of view of sound conduction, and sound-waves can to some extent affect the inner ear by conduction from the teeth and through the bones of the head. When the temporal bone is examined, it is found to contain a double piece of apparatus, all of which is undoubtedly of the same evolutionary origin, and which appears to be supplied by one and the same nerve.

This auditory nerve, however, is now known to consist of two distinct parts, with different centres in the brain, and only one of these is really auditory. The other runs to the brain from what are called the semicircular canals, now known to be no part of the organ of hearing. They have a very important function, as we shall see, but it has nothing to do with hearing. Their structure plainly indicates that they are concerned with the direction of something, and the view was long held that they inform us as to the direction of sounds, but that is now known to be erroneous.

The Primitive Ear in Animals Which Has Been Further Developed in Man

In invertebrate animals we find a sac, containing hard material, and called the otolith sac. In the lowest group of fishes a single semicircular canal is added to this sac. In the higher fishes and all other vertebrates three semicircular canals are developed, and the otolith sac is divided into two. From one of these two portions there is developed, in reptiles, birds, and mammals, a spiral canal, like the shell of a snail, which is called the cochlea. This it is which has taken over, in ourselves, the whole of the function of hearing, and has developed within itself the extraordinary

structure which is known as the organ of Corti, and corresponds to the retina of the eye. It is to be admitted, however, that the retina is really nothing less than brain, while the organ of Corti is developed from the surface of the body.

The cochlea consists of two and a half spiral turns round a central supporting pillar. But this spiral canal is subdivided by plates of bone and membrane into three staircases, or scalæ, as the early Italian anatomists called them.

The Wonderful Vibratory Organ of the Inner Ear

Upon the membranous partition, which extends throughout the two and a half turns of the canal, we find the special structure called the organ of Corti. This is a very complicated arrangement of cells, placed upon a vast number of parallel fibres rather like piano wires, which are longer at the base of the cochlea, and gradually get shorter as the staircase across which they are stretched gets narrower. The resemblance between these regularly shortening fibres and the wires in a piano or other stringed instruments is too striking to be overlooked, and it has been supposed that these fibres act like the wires of a piano, responding to various vibrations that reach them, according to their length, and thus affecting the particular part of the organ of Corti which lies upon them.

In this organ itself the essential elements are the hair-cells of Corti, something like fifteen thousand in number, which are long, plump cells, having fibres of the auditory nerve encircling their bases, while their upper ends are provided with several short, stiff hairs, bathed in the fluid that fills the cochlea. These are undoubtedly the all-important cells of the inner ear, and are to be looked upon as exactly corresponding to the rods and cones, or perhaps more especially to the cones, of the retina.

Where Sound Becomes Changed to Nerve Impulses and the Brain Hears

Whatever may be thought of the resonance or piano theory, which was stated in its original form by the great German Helmholtz, it seems impossible not to suppose that the hairs of the hair-cells must have an important function, since we know that they are bathed in the very fluid in which the sound-waves are certainly transmitted.

Only prolonged microscopic study of the organ of Corti can give any real idea of its complexity, and the completeness of the arrangements which it comprises for the reception of sound-waves. Thus, for instance, there appears to be a membrane which damps down the vibrations after they have passed the cells upon which they act, and it is also noteworthy that there are no blood-vessels in this organ, for undoubtedly the alterations in the blood-pressure would sadly interfere with hearing if there were. The nerve supply is extremely rich, and the ultimate fibres lose their sheaths and envelop the pointed ends of the hair-cells. It is at this point that we have to face the mystery which we met in the retina. Light goes no further than the rods and cones, and sound goes no further than the hair-cells of Corti. What travels to the brain through the auditory nerve is not sound, but nerve-impulses, and it is a further illustration of the "law of specific sensations" that by whatever means the auditory nerve may be stimulated, the result is sensations of sound. These sensations may be very tiresome, as many victims of singing in the ears, or "tinnitus aurium," know to their cost.

The Amazing and Unexplained Possibilities of the Finest Sense of Hearing

Disturbances in the circulation in any part of the middle or inner ear, spasm of the tensor tympani or stapedius muscles, and other local causes are thus able to excite the auditory nerve, and the result is sound-sensation, just as pain follows any excitation of its specific nerves, and vision follows any excitation of the optic nerves.

Vastly complicated as the cochlea is, it affords us little clue to the astonishing possibilities of the sense of hearing, as they are exhibited by the trained musician. The ear of a good violinist can distinguish fifty distinct notes or levels of pitch between F and G in the middle of the piano. The range of the eye for light extends to rather less than one octave—*i.e.*, roughly, from about 400 to about 750 millions of millions of ether-waves in a second. The ear has a much wider range, extending considerably beyond the seven octaves of an ordinary piano in both directions. The lowest notes perceptible by the ear consist of about twelve to sixteen vibrations per second, and the highest, like the bat's squeak, run up to thirty-five or forty thousand vibrations per second. People of trained musical ear can distinguish more than twelve thousand separate notes or qualities of sensation between these two extremes.

Ever since the time of Helmholtz one theory has followed another in the attempt to explain how these thousands of different

sensation-qualities are distinguished. There is much to be said for the piano or resonance theory, in one form or another, but much also to be said against it. Sound-waves are too large to answer at all well to the requirements of anything so tiny as the organ of Corti. Helmholtz was assured that, by some material mechanism of the many with which it is provided, the organ of Corti analyses complex vibrations, such as nearly all sounds are made of, especially musical sounds, and so sends to the brain separate and distinct impulses to correspond to each part of, say, a musical chord.

The Brain Reached Physically, but Ineffectively, by Direct Sound

But it is impossible to maintain that the cochlea is capable of analysing complex vibrations. All we can credit it with is extreme acuteness of perception, and the power of sending nerve-impulses which reach the brain *en masse*, so to say, and are dealt with by it. The nineteenth century did its best to furnish a mechanical explanation, but the laws of mechanics forbid any such explanation to suffice for the case of the cochlea. We must go back to the brain, where mechanics and every other department of physical science break down. There can be no doubt that it was not physically correct to say that sound stops at the cochlea, as light stops at the retina. In point of fact sound-vibrations must go right through the head, including the brain and the auditory centre. This is the one case where a sensory stimulus actually strikes the sensory centre. Vision, touch, smell, taste—all these are excluded from direct action on the brain, and the stimulus requires to do all it can do at some remote nerve terminal. But sound-waves are not so excluded, and actually traverse the auditory centre itself.

The Brain Aroused Only Through the Appointed Mechanism of the Ear

We might very reasonably suppose that the whole aural apparatus is therefore more or less of a superfluity, and that our explanations of hearing should try to deal with the direct action of sound-waves upon the brain. But pathology quickly tells us that hearing is made impossible if the auditory apparatus breaks down in any way, and that the problem here is therefore the same, after all, as that of the other senses. If the auditory nerves be thrown out of action, the centres are found to be quite unaffected by the sound-waves which must pass through them. And the fact is not without a parallel, for it is known that the cerebral centres for touch-sensation are entirely insensitive when they themselves are touched. Only through the appointed nerves can any of these cerebral centres be aroused. It is therefore practically, though not physically, correct to say that sound stops at the cochlea as light does at the retina.

We are thrown back on the auditory centre and its properties if we desire to learn how the ear analyses and identifies sounds. Anatomists may call the cochlea the " inner ear," but the real " inward ear," like the " inward eye," is to be found in the *cortex cerebri* alone. We have already observed the range of its capacities, but their quality has scarcely been suggested. Many musical people have what is called " absolute pitch," which means that they can identify the pitch of any musical note they hear. The brain can carry its memory of pitch so that the hearer can say, at once, and without calculation or thought, that the motor-horn in the street sounds A, or that a whistle is in F sharp, and so on.

The Fine Appreciation of Sound that is More Remarkable than a Sense of Absolute Pitch

But the study of acoustics shows that the ordinary qualities of ordinary ears are really more remarkable than this sense of absolute pitch. When we distinguish the same note sounded by a horn, an organ, a piano, a violin, a clarinet, a friend's voice, and a second friend's voice, our ears prove themselves capable of distinguishing and identifying the minute " overtones," or " harmonics," which constitute the difference between these different sounds, all of which are of the same fundamental pitch.

Orchestral and choral conductors possess fineness of aural discrimination which is almost incredible, readily picking out a wrong note played by one of perhaps a hundred and twenty instrumentalists. Yet acoustics tell us that separate sound-waves from each instrument cannot possibly reach the ear when we hear an orchestral chord. When more notes than one are sounded simultaneously, the resulting wave-form is a complex product, which is none of its constituents, and yet is affected by each of them. But the ear is capable of, so to say, reconstructing in its entirety the sound-wave which does not really exist at all as such, but only as a modifying factor in the complex blended wave which reaches the ear. It will be evident that, since a particle of air cannot be simultaneously moving in two different directions, what happens when two different waves travel through the same

air is that neither wave can survive as such. They destroy each other, and produce something else. But from the features of that something else the musician's ear can readily reconstruct and imagine that it hears each or any of the waves which were destroyed in order to produce it. What, then, can we positively assert of the cortical centre? For instance, must we begin by assuming that there is a separate process, a separate substance, or a separate cell, for each of the twelve thousand distinct aural sensations which a good ear can identify?

Appreciation of Gradations of Sound Similar to Appreciation of Gradations of Colour

The answer to this must be negative. There cannot be so many distinct processes, but there must be a much smaller number of distinct processes which blend with one another in varying proportions so as to produce all the different pure tones, twelve thousand or so in number, which a good ear can identify.

This is rendered the more probable by the very definite evidence of vision, when we saw that the infinite gradations of colour which the eye can distinguish are dependent not upon a separate provision, somewhere, for every possible tint, but upon the varying proportions in which very few elementary or primary sensations are excited. In the case of the eye most students believe that four primary kinds of sensation will account for all the possibilities of colour-vision, and no existing theory demands more than six. In the case of the ear the number must be larger, though probably not more than fifty. This, however, is a very small number compared with twelve thousand, and it seems necessary to believe that every note we can hear depends upon a blending of these primary pitch-sensations, each of which, perhaps, corresponds to some definite substance in the auditory centre.

Musical Discrimination Dependent on the Proportions of a Few Primary Elements

Perhaps the best of the many pieces of evidence which suggest that our musical discrimination depends upon so few primary elements is thus well stated by a recent authority.

"If each distinguishable tone were an elementary quality, we should expect that when the air is made to vibrate at a steadily increasing rate, as when a violinist runs his finger up the bowed string, or the length of a whistle-pipe is regularly diminished while its note is sounded, the pitch would rise by a series of steps from one elementary quality to another; but this is not the case, the transition is perfectly smooth and continuous. A concrete example will make this point clearer: If two elementary qualities are excited by 196 and 200 vibrations per second respectively and are just perceptibly different in pitch, then the tone excited by 198 vibrations per second should be identical in quality with either 196 or 200, it should be of one or other of these elementary qualities. But we know that it is identical with neither, for it is distinguishable from 194, from which 196 is not distinguishable, and it is distinguishable from 202, from which 200 is not distinguishable. The rise in pitch seems, in fact, to be perfectly continuous and the differences of pitch infinite in number; such continuous variation of quality indicates that, as in the case of the continuous changes of quality of the colour-scale, the change is due to a continuous change in the proportion of two or more constituents of a complex."

The Lack of Satisfactory Studies of the Brains of the Musical and Non-Musical

Thus the musician will see that the continuity of his sense of pitch, and his capacity to appreciate pitch at any level, and to hear perfectly no matter to what exact pitch his instruments are tuned, depend upon the fashion in which pitch is appreciated—by the proportions in which certain elementary pitch-sensations are blended. But so far it is impossible to say what are the "primary pitches," corresponding to the "primary colours" in colour-vision.

Microscopic study of the auditory centre in the temporal lobe of the *cortex cerebri* has hitherto shown very little. This area of cortex, which has such a distinctive function, is not markedly differentiated in cell-structure from the areas which surround it. For instance, we find no marked local peculiarities like the large pyramidal cells of the psycho-motor area. All we can say is that the extent of this area is large in man. There is no evidence as yet to show that its microscopic structure is peculiar in tone-deaf persons, who correspond to colour-blind persons fairly closely, nor have we as yet any comparative study of the cortex in non-musical and musical persons, and in very great musicians.

It will be for future ages to make these inquiries when a different state of public opinion enables students to have access to different types of brains, when their former owners have no further use for them, as in the case of a few distinguished persons who have made definite testamentary disposition of their brains for the purposes

of science, such as the late Professor Goldwin Smith and Miss Florence Nightingale. It can be asserted positively, however, that nowhere is inheritance of psychical characters more evident than in this realm, and further psychological analysis of the musical sense will probably enable us to assign Mendelian ratios to the inheritance of certain of its constituents.

The Functions of the Mechanism of the Ear Only Those of a Messenger

We saw that the functions of the retina, though that is historically a part of the brain, are very humble compared with those of the visual cortex, as it is often called for short. Just so is it with the auditory cortex and the organ of Corti. The receptive organ plays no part in memory, perception, or any creative process. It simply receives impressions, and sends nerve-currents accordingly. All the rest is done by the cortex. All memories of sounds are stored there; it is the seat of "absolute pitch" in those who possess it; and the unknown physical agents by which we distinguish pitch at all must have their seat there. It is the auditory cortex that is at work in dreams of hearing and in all forms of auditory hallucinations and delusions (as distinguished from singing in the ears and similar disturbances). When we hear voices talking nonsense or wickedness or inspired wisdom, setting us to do deeds like a Joan of Arc, or to write noble words, it is the auditory cortex, the real inward ear, that is involved, whatever the whole explanation of these facts may be.

The true *status* of the auditory cortex in relation to musical conception and creation is furnished by the celebrated instance of one of the greatest of all musicians, Ludwig van Beethoven.

The Auditory Cortex of the Brain the Sole Seat of Musical Memory

Of course, there are no grounds for the popular view that musicians compose at the piano. They may improvise or "play about" there, but the musician composes at his desk, just as an author writes. His auditory apparatus is not concerned in the least, but his auditory cortex is indispensable. In destruction of the auditory cortex all possibility of musical appreciation, let alone creation, vanishes.

Beethoven was early attacked with slight deafness, which gradually increased until, for many of his latter years, he was stone-deaf. It may be asked whether we can now say if this deafness was of central origin, in the cortex of the composer, or had its cause somewhere in the aural apparatus; and that question can be answered at any time, without the aid of any examination, from the simple fact that during those years of absolute deafness Beethoven was composing some of the noblest and most beautiful musical compositions in the whole literature of the art. Assuredly his auditory cortex was intact, and by means of it he was enabled to conceive and create melodies, harmonies and combinations of tone-colour which he never heard at all, even though he sometimes conducted performances of them, and yet which, in some sense no less true, he must have heard incomparably.

It is to be observed, then, that the auditory cortex is not merely capable of recalling sounds or melodies, as when we think of a tune, and, so to say, hum it mentally, which anyone can do, but it is also capable of conceiving sounds and sound combinations which it has never heard and never can hear.

People Who Think by Sight and People Who Think by Sound

Recent researches have shown that the great majority of people can be classified in one or other of two psychological types, corresponding to the two great senses described in this and the preceding chapter. These classes sometimes are called the "visuals" and the "auditives" respectively. The "visuals" or visualisers seem to conduct the majority of their mental processes by visual symbolism. They "think in pictures": their mental method is graphic. The majority of women belong to this group, and, of course, the majority of painters, sculptors, architects, decorators, engineers, and mechanically gifted people. Such people readily apprehend space-relations, and can conceive new ones. If they possess this power in high degree they may paint fine pictures, build new types of architecture, conceive new machines.

The auditives, on the other hand, think more in sounds and words, and not in pictures. They naturally include the musicians, the men of letters, and the scientific and philosophic people. They are more numerous among men than among women. They notice things around them less, and are more commonly credited with being "absent-minded." If great development of either is rare, vastly rarer is great development of both in one and the same individual. Such individuals stand out as the few supreme examples of what we call versatility, and of these the most notable representative in the history of the world is Leonardo da Vinci.

THE DESCENT OF MAN: HOGARTH'S PICTURE OF THE DEMORALISING REIGN OF ALCOHOL

A SCENE IN OLD COVENT GARDEN AS DEPICTED BY WILLIAM HOGARTH IN "THE RAKE'S PROGRESS," NOW SHOWN IN THE SOANE MUSEUM

PROBLEMS OF ALCOHOL

Its Importance as a Chemical Compound When Used Outside the Human Body

WHAT BECOMES OF IT WITHIN THE BODY

THE foregoing chapters have prepared us in some measure for the almost impossible task of discussing alcohol fairly and usefully. This cannot be done in a little space, nor can it be assisted by any dogmatic or personal assertions, as that alcohol is a poison, or that it makes one feel better. The problem affects our feelings and prejudices and antipathies and moral sense, but it is really a scientific problem, and in this place it must be treated as such. It is something that we have already reached some general principles as to foods, drugs, and poisons, which will help us here, but our first concern must be to define the substance we are dealing with. It is, on all accounts, one of the most important chemical compounds in the world.

In the language of chemistry, there is a long series of substances known as alcohols, in correspondence with a similar and closely related series of ethers. For convenience, men usually mean a particular alcohol and a particular ether (the corresponding ether, in fact) when they use the terms without qualification. These are the second of the series, the first being known as methyl alcohol and methyl ether respectively. Methyl alcohol is of interest to us here, because its highly objectionable taste and smell practically preclude the use as a beverage of anything that contains it. The Legislature taxes alcoholic beverages, but does not wish to tax alcohol which is used for other purposes. However, people are always liable to drink alcoholic liquors, for whatever purpose they were intended, and thus defeat the purposes of the Excise. We therefore add to ordinary alcohol intended for use in spirit-lamps, etc., a proportion of methyl alcohol, and the spirit is then said to be methylated. Methylated spirit is occasionally drunk by pitiable inebriates who can obtain nothing else, but, on the whole, the method of making the spirit undrinkable by adding methyl alcohol to it is effective.

However, a large and important problem remains for scientific ingenuity and legislative intelligence to solve, and it may briefly be named here. What we require for many commercial purposes, which daily increase, and may soon extend to the use of alcohol, like petrol, in internal-combustion engines, is a spirit which shall be as nearly pure alcohol as possible, but which shall be undrinkable, either as such or when diluted or matured. It is said that a huge fortune awaits the inventor of such a substance, but the problem is not simple. And we further require a Legislature which shall do as it thinks fit in the taxing of alcohol for drinking, as most or all Legislatures do, but shall offer no obstacle whatever to the freest possible use of alcohol for all other purposes. For whatever conclusions we may reach as to the action of alcohol within a living organism, it is hard to beat for its uses outside the body.

It is a splendid fuel, clean and efficient and cheap; it is a wonderful cleanser; an almost unrivalled preservative, in consequence of its powerfully destructive action upon living matter, such as that of the microbes which cause fermentation or putrefaction; and it is a very nearly universal solvent, thus being of use for a host of chemical purposes. A cheap and pure and ever-swelling stream of alcohol is thus an essential for the industrial and material progress of any modern community; and it is most unfortunate that its liability to be drunk, and the consequent attentions of the Treasury, should interfere with the necessary and legitimate purposes for which there is an ever-increasing demand. For the problems of fuel and power are basal for a modern nation; and

when we look at the natural history of this substance we find that, when compared, for instance, with such geological legacies as coal and petrol, it occupies a very extraordinary position.

The "name in full" of the substance in question is ethyl alcohol, corresponding to ethyl ether, which is so familiar in surgery. The two substances are closely allied chemically, differing only by the lack of the elements of water in the ether, which is an oxide, while alcohol is the corresponding hydrate—*i.e.*, "watered"; and they are largely used together, with the addition of chloroform, in the well-known "A.C.E. mixture"—alcohol, chloroform, ether—of the anæsthetists. Ethyl alcohol—as we shall call it for the last time—may be made by chemistry in a variety of ways, but in Nature it has one definite origin. If we take a typical sugar and examine its chemical constitution, we find that it consists of carbon, hydrogen, and oxygen atoms. Under certain conditions this large and complicated molecule, mysteriously made by the green plant, can be broken up into a number of smaller molecules of two kinds.

The Natural Formation of Alcohol and Its Evaporation in Baking

The two substances thus formed are carbonic acid gas and alcohol; and the process is illustrated in every loaf of bread we eat—except aerated bread, into which the carbonic acid has been forced from without. When dough "rises," it is raised by the formation of carbonic acid gas within it, by the decomposition of sugar. Alcohol is formed at the same time, and evaporates. Very many scores of thousands of pounds' worth of alcohol have been estimated to be thus lost yearly in the bakehouses of London alone. The alcohol thus formed consists, like sugar, of atoms of carbon, hydrogen, and oxygen, but in very different proportions—viz., two of carbon, six of hydrogen, and one of oxygen in each molecule, or C_2H_6O, in the elegant and handy formula of the chemist.

The composition of alcohol is very important, even when stated so simply as this, for it shows at a glance that this must be a combustible thing, and also what the products of its *perfect* combustion—but note the adjective—must be. Plainly it must have a high fuel-value, with all that carbon and hydrogen to be satisfied in their demand for oxygen, of which they now have only one atom between them. Each carbon atom wants two oxygen atoms to make carbonic acid, CO_2, and every two hydrogen atoms will take one oxygen atom to make water, H_2O, so that plainly each molecule of alcohol is equal to taking up six atoms of oxygen, besides the one it has, for its complete combustion. We also observe that the products of combustion, carbonic acid and water, are extremely familiar to us; that they are the normal products of the combustion by which our bodies maintain their heat and energy, and that we have ample means of getting rid of them safely and quickly. These facts must be appreciated if we are to do justice to the argument, long maintained by physiologists, that alcohol must be a food in virtue of its chemical composition.

Alcohol Formed from Sugar and Decomposed into Acetic Acid by Typical Fermentations

But we must first look further at the origin and fate of alcohol in Nature. It was formed, we saw, from sugar, and now we learn that, in its turn, it is decomposed, and, by a very simple chemical change, is converted into acetic acid, the essential ingredient of vinegar—in French vin-aigre *i.e.*, "wine sour"—which is spontaneously produced from wine or other alcoholic liquors under certain conditions. Both of these processes—that by which alcohol is made and that by which it is destroyed—are typical fermentations. The first is effected by certain chemical ferments which have lately been successfully isolated from the microscopic body of the yeast-fungus, the *saccharomyces*, or sugar-mould. The second is effected by a still simpler type of fungus, the *bacillus aceticus*. This microbe is unique in Nature, in virtue of its power of living by means of alcohol. The process is desirable when we want vinegar for itself, or for the isolation of acetic acid from it, but otherwise it is wasteful of a valuable substance, which should not be frittered away upon the purposes of a microbe.

Alcohol in Sufficient Concentration Fatal to All Forms of Life

It is especially the formation, and not the decomposition, of alcohol that first concerns us, though we note how certain living cells, acting upon it, by no means necessarily yield such harmless or manageable products as carbonic acid and water. The fact may illuminate many other facts at a later stage. But the formation of alcohol is of immense interest. It can nowadays, thanks to the work of the great French chemist Berthelot, be put together artificially from its elements in the laboratory. But under natural conditions we meet with it in only two situations, of which the second has only recently

been discovered. We find it, first and almost exclusively, produced in the vegetable world by the alcoholic fermentation of sugar, the agent being the yeast-fungus, so that alcohol has been called "the toxin of the yeast-fungus," like the toxins of other fungi, such as the diphtheria bacillus or the tubercle bacillus. No exception is known to the rule that, in sufficient concentration, alcohol is fatal to all forms of life—the fact which gives it its antiseptic value. The yeast-fungus which produces it may well be expected to be resistant to its action, and is so; but even in this case we find that when the fermenting fluid comes to contain a certain proportion of alcohol the fungi begin to die, the process is arrested, and if the fermentation is desired to proceed the alcohol must therefore be continuously removed fast enough to permit it.

Above all, at this particular stage of national development, a word must be said as to the importance of this familiar process. Wherever the green plant exists, there we find starch, which leads to sugar, and there we also find the yeast-fungus to form alcohol. Looked at as a source of power when subjected to combustion, this substance is therefore of extraordinary importance.

Extraordinary Importance of Alcohol as a Universal Source of Power

Coal, oil, petrol—these, as we have said, are geological legacies, and they cannot be used, like other capital, to yield interest and remain unimpaired. Further, their extraction involves serious economic problems, and tends to become a monopoly. Also, the crude combustion of coal is wasteful, and extremely injurious to the health of citizens as it is at present practised. But alcohol, an alternative source of power, can be continuously produced, with extreme cheapness, wherever there is any soil upon which the sun shines. This source of power involves no expenditure and exhaustion of a nation's natural capital, but essentially depends upon the use of its natural income—namely, the sunlight which falls upon its surface. The time must necessarily arrive, and at no distant date, when considerations like these will penetrate even the stout walls of our legislative chambers. Meanwhile we shall have to decide how far the combustibility of alcohol, upon which its great economic uses depend, applies to the conditions and the relatively low temperature of the human body, or, if no combustion can occur there, what becomes of the large quantities of alcohol taken into it with unconcern.

But first we must go on to note the second, and most remarkable, situation in which alcohol has lately been discovered in Nature. The fact is of high importance, because of its interpretation. Alcohol has been found to occur normally in the human body, no doubt in very minute quantities, but definitely and constantly none the less. It occurs in the muscles, and is found to be a product of muscular action. The chemical interpretation of this fact is in part clear. It is that a form of sugar is the normal fuel of muscular tissue, and that, apparently, when this sugar is oxidised for the production of muscular energy, alcohol is one of the products, or a stage in the series, or one series, of the products.

Alcohol Made in the Human Body and Destroyed in the Body

It is impossible to be more definite at present. But at least we can be sure that the alcohol does not remain as such; for if that were the case, either it would shortly accumulate and kill the muscle, or else it would require to be excreted by the kidneys or lungs, or both. But we find no alcohol whatever in any of the excreta of an animal or a human being to whom alcohol has not been administered. It follows, therefore, that the alcohol made in the muscles must be destroyed in the body; and, as we never find alcohol in the blood unless the drug has been administered, we must conclude that the alcohol formed from the sugar of the muscles—doubtless by some ferment they contain, comparable to that of the yeast-fungus—must be decomposed in the muscle. What occurs has yet to be ascertained, but the writer is willing to suggest that one or more of the further products of the alcohol may prove to be, or to contribute towards, the unknown but certainly real fatigue-toxins which accumulate in an exercised muscle and gradually cause fatigue. This is an obscure and interesting department of physiological chemistry which requires much further investigation.

The Presence of Alcohol in the Body No Warrant for Putting More There

It goes without saying that this recent discovery of the production of alcohol in the normal body under certain normal conditions has been seized upon by its few surviving champions as an argument in favour of its utility and the natural propriety of consuming it. We need only consider the charming application of this argument to the case of any other products of the body which may occur to us, in order to surmise that the case for alcohol must be

fairly desperate today, even in the eyes of its champions. In point of fact, the formation of alcohol in the body proves nothing, for the body is known to produce the harmless, necessary substance water; and, on the other hand, an interminable list of poisons, such as carbonic acid and uric acid. The question whether alcohol is to be classed with water, on the one hand, or any of these others on the other hand, remains where it was. Nothing is altered, except the case of our belief in the honesty of those who advance such arguments.

They must not blind us, by their dubious advocacy, to the fact that the combustion of alcohol in the muscles, even if it be only partial, must involve the production of energy in proportion to the degree in which it occurs. But even supposing this oxidation to be such as serves the muscle, we are not entitled to argue that the administration of alcohol by the mouth would serve the body as the formation and destruction of alcohol inside a muscle is supposed to serve on this assumption. For, in the artificial case, the alcohol must be conveyed to the muscle by the blood, in which no trace of alcohol ever occurs normally, and in which it is therefore an essentially foreign substance, and upon which experiment has proved it to exercise a definitely poisonous and destructive action.

The Rapidity with which the Body Gets Rid of Alcohol

This is perhaps the most convincing of the various answers to those who have argued for the administration of alcohol by the mouth because it is formed in muscles—an argument which urges us to breathe carbonic acid, which is also produced in muscles.

But this new discovery of the production and combustion of alcohol, in however minute quantities, in the normal working of the body, naturally leads us on to the first question which the physiologist must ask of this or any other thing that is introduced into the body: What becomes of it? Unless we can answer this question of any food or alleged food, of any drug or poison, we cannot make much progress. We know that the law of the "conservation of matter"—apart from radio-active decomposition of atoms—obtains in the body as out of it. If we introduce any element or compound into the body it either stays there, or leaves the body unchanged, or leaves the body in some altered form, or does any two of these things, or all three. If it remains in the body, then its action will be cumulative, as is the case with mercury, and the fact may have mortal consequences. That is very far from being the case with alcohol. It does not accumulate in the body, because the body deals with it, in two distinct ways, as we shall see. No doubt a proportion of alcohol is always present in the blood of those who regularly take more than a certain small or moderate quantity, which varies with the individual and with many other factors, but that does not mean that the drug is cumulative. Let the heaviest drinker stop drinking, no matter after how many years, and in a period of time only to be measured by hours, probably—perhaps thirty-six or so—no alcohol will be found in his blood.

The Body's Power of Oxidising Alcohol Beyond Recognition

The body therefore deals with this substance, and it does so as quickly, thoroughly, and variously as it can; no poison is known which the body makes heartier efforts to dispose of. The stories of the "spontaneous combustion" of drunkards are mythical.

We have seen that alcohol is combustible; and the first question is to determine whether it is oxidised or burnt in the body. We might expect this to be impossible, for certainly alcohol cannot be burnt outside the body at any such temperature as 99° F., which is approximately that of the blood in the deeper and warmer parts of the body. But the body has special means of its own, and can, for instance, burn sugar at that temperature, which we cannot do outside it. The question must be therefore subjected to experiment, and then we find that under certain conditions *all* the alcohol given must be oxidised in the body, for none of it can be found in any of the excretions; and under any conditions and in any dosage we never succeed in recovering from the excretions all the alcohol given. Alcohol is therefore oxidised beyond recognition in the body; it is, in fact, turned into some other thing or things.

The Body's Protection Found in Changing Alcohol to Something Less Harmful

Here, again, until recent years, its champions permitted themselves the expensive luxury of a bad argument, assuming that, because alcohol is destroyed in the body, it is therefore oxidised into carbonic acid and water—the first readily removed, the second harmless in any case—and that, in being so oxidised, it yields the corresponding measure of energy for the purposes of the body. But no proof of this has ever been attempted; and our

entire lack of any title to assume that this is what happens is furnished by the best known and most natural case of the destruction of alcohol by fermentation at low temperatures, in which, as we have seen, the product is not carbonic acid and water, but a new and by no means inert or negligible substance, called acetic acid.

A second comment upon this oxidation of alcohol within the body is that it is only a fact parallel to the oxidation of many other poisons, such as morphine. When that drug is administered the body proceeds to destroy it as fast as possible by oxidation. No one, however, proceeds to argue that morphine is therefore a food and a valuable and legitimate source of energy; but then it is to no one's interest to advance a palpably bad argument in this case. The probability is very high that the case of alcohol is similar to that of numerous other oxidisable poisons: the body seeks to protect itself by oxidising them, and thus converting them, if possible, into something harmless, or less harmful—which is probably the more accurate statement both for morphine and alcohol. But there is a notable and important difference—namely, that the body can deal with vastly larger quantities of alcohol than of morphine.

What Happens to Alcohol that Ceases to be Alcohol in the Body—an Unsolved Problem

Careful experiment has shown that if it be taken in small doses at a time, well diluted, at sufficiently wide intervals throughout the whole period, about one and a half ounces of alcohol can be administered in twenty-four hours, without any of the drug being recoverable from the excreta during that period or after it. Roughly speaking, this quantity corresponds to about three ounces of whisky in that period, but they would require to be taken as no form of alcoholic beverage ever is taken except for experimental purposes, if none of the drug were to be recovered. Calculations can be, and have been, readily made showing that the perfect combustion of this quantity of alcohol daily must involve the production of a very substantial and valuable quantity of energy for the purposes of the body. The only thing lacking here is any evidence that the combustion is perfect, or remotely approaches perfection. That has been assumed, and the great name of science has been taken in vain, by authors who were, of course, perfectly familiar with the formation of acetic acid from alcohol.

In point of fact, no one yet knows what happens to the alcohol which ceases to be alcohol in the body. That it ceases to be alcohol is the sole fact which science has discovered so far, and therefore the sole fact which it is entitled to state, but the question cannot and will not rest there, for we now want to know not only what happens to alcohol administered to the body and not excreted as such, but also to the alcohol which is normally made in the body and not excreted as such. These questions are now the subject of careful inquiry. Meanwhile we proceed to study the second mode in which the body deals with alcohol administered to it beyond a certain small quantity under certain strictly limited conditions.

The Variability in the Action of Volatile Drugs

As we have seen, the body excretes it as it is; and observation has revealed several very remarkable facts about this process—facts which chiefly depend upon the high volatility of alcohol, and the extreme quickness with which it can pass through most or all organic membranes, such as it encounters in the walls of the blood-vessels and elsewhere.

This easy and rapid passage of alcohol in almost all directions has results which are similar to those found in the case of other drugs with the same property, as, for instance, iodide of potassium, a very valuable and widely used and potent medicament. The iodide is found to be leaving the blood by the kidneys a few minutes after it is swallowed; but, on the other hand, small quantities may remain in the body for not merely hours, but days, after a single dose, because the drug is so easily absorbed by the blood from the stomach, is excreted in the saliva into the mouth, is swallowed again, and so goes on a curious circle which may last a very long time indeed.

Alcohol Highly Volatile and yet Capable of Being Long Retained

Similarly, it has been shown that a single dose of alcohol may exhibit its action for from thirty to thirty-six hours, so that most people are continually under its action for the whole of adult life. Yet the greater part of such a dose is removed from the body with great speed. The remainder may be accounted for in two ways. Some of it goes on a curious course rather like iodide of potassium. Absorbed from the bowel or stomach, it is carried to the liver, which largely exists in order to reject unsuitable constituents of the blood which reaches it from these great surfaces of

absorption, and the liver stops it and returns it to the bowel in the bile. But there it is reabsorbed and goes to the liver again. This circular and self-defeating process is probably accountable for the peculiar liability of the liver to be injured by alcoholism. The hobnailed liver of the drunkard, the failure of which ultimately kills him, is one which has itself gone to its death in the effort to protect the noble organs—above all, the brain—from this substance; and apparently the misfortune for the liver is that, by the mechanism we have mentioned, it may be compelled to deal with a given portion of alcohol not once but many times.

The Peculiar Affinity of Alcohol for Nervous Tissue

The second way in which a dose of alcohol may be accounted for, apart from its actual excretion, and in which we have the key to the prolonged action of so mobile a drug, is its peculiar affinity for nervous tissue. The subject is difficult and still obscure. Fifteen years and more ago it was known that this peculiar affinity exists, for alcohol could even then be chemically detected post-mortem in the brain, and in the fluid which is contained inside the brain, when no trace of it could be found elsewhere. This fact goes with the observed properties of alcohol, which is, above all, a narcotic—one of the class of nervous poisons. Always its action is pre-eminently upon nervous tissue, from the highest levels of the brain downwards. We now know that a real chemical affinity exists between alcohol and nerve-cells, and that thus a certain portion of this extremely mobile, volatile, diffusible substance, which enters and begins to leave the blood and the body a few minutes after swallowing, is nevertheless detained or trapped *en route*, whenever it happens to run in blood-vessels that supply the nervous system, and may there produce results for many hours.

The Study of Alcohol in Comparison with Similar and Contrary Drugs

Recently the comparative method has thrown light on these observations. It is of little use to study any one drug or food by itself. Similar and contrary drugs should be compared and contrasted. Alcohol, chloroform, ether, allied chemically, notably similar in physical properties, and no less similar in their action upon the nervous system as typical narcotics and anæsthetics, and all three often the object of similar cravings on the part of unfortunate persons, require to be studied in parallel if their similarity of action is to be explained. Such comparative study seems to show that these three substances, and certain others chemically allied to them, but less familiar, have the property of being able to dissolve the peculiar fatty materials, called lipoids, which are believed to furnish a sort of protective envelope for nerve-cells; and it is this solvent action upon the lipoids which gives these drugs their access to the much guarded privacy of the nerve-cells, and thus leads to arrest of their action. Such, at any rate, is the probable and most recent explanation of this part of the action of these and other anæsthetics.

We had to mention that matter here, because we had to understand why so prolonged results follow the administration of a drug which, we asserted, is excreted with extreme rapidity. That excretion must be further studied. The rapidity of the processes is astonishing. The absorption into the blood of alcohol administered when the upper part of the alimentary canal is empty begins within a few seconds, or, rather, begins at once. It is estimated that something like one minute would suffice for a blood corpuscle to make the round of the circulation. No wonder that the action of alcohol is quickly exerted.

The Organs that Protect the Body from Alcohol the First to Suffer

But it leaves the blood with no less speed. When it was applied to an absorbent surface it passed into the blood "like lightning"; when the blood carries it to an excreting surface it seems to leave the blood as quickly. This does not mean that the white cells, for instance, may not retain portions of it, for they doubtless do, just as nerve-cells do, but the point is that the body starts instantly with the business of excretion. Every surface and tissue whose business is of this kind takes a hand. We have seen the behaviour of the liver, and now we have to observe the behaviour of the organs reached by that proportion of the alcohol absorbed which the liver failed to arrest; for the blood-stream is quick, and though the liver stops much, it can never stop more than a proportion, as yet undefined.

The chief organs of excretion are now the kidneys and the lungs, the latter being available for any substance, such as alcohol, which is volatile. Accordingly, the drug is found in the secretion of the kidneys and in the expired air in a very few minutes—as few as twenty—and a diminishing proportion of it continues to be found there fo

hours afterwards. We may note that the kidneys closely follow the liver in their liability to damage by alcohol, probably because the drug must have more action upon those cells which select it from the blood than upon those which allow it to pass by them more readily. And we note, further, the recent demonstration of the potent action of alcohol in weakening the resistance of the lungs to consumption, as we shall see later. The general conclusion seems to be that the local-destructive action of alcohol falls most severely upon those organs which do their best to dispose of it for the protection of the body as a whole, and which are thus liable to special damage.

The Importance of the Study of Alcohol as a Separate Ingredient

Our primary question as to what happens to alcohol when taken into the body has now been answered with some definiteness, though much more is needed, and we are in a position to proceed. Of course, the reader clearly understands that when we say alcohol we mean the definite substance, of definite chemical constitution, which chemists call ethyl alcohol. The attempt to deal, at a gulp, with all the variety of substances contained in alcoholic beverages may succeed, in swallowing, but not in science. No one drinks pure alcohol and water. Many alcoholic beverages contain a variety of substances which are totally dissimilar in origin and properties—beer, for instance. Science only begins with the separate study and appreciation of the various ingredients in such beverages, just where popular opinion and advertisement leave off. Here our concern is with the alcohol contained in these beverages, or in any pharmaceutical preparation, such as tinctures and essences, or elsewhere.

The Bulk of the Beverage Containing the Alcohol of Small Account

It is essential, also, if our inquiry is to be useful, to realise that the quantity of this substance taken is the essential thing, and not the bulk of fluid in which it is taken. Whisky and lager beer are both alcoholic fluids, in that they both contain alcohol, but unless we know that the one is nearly half alcohol and that the other is only about one-fiftieth alcohol, we can make no useful study of either.

What matters in alcoholic beverages is not their water, nor their flavouring matter, nor their colouring matter, but their alcohol. This is now proved by the chemist and the physiologist, and it should be recognised by the Legislature. If we assume that the State does well, for whatever reason, to tax alcoholic liquors, because they are alcoholic, it is clear to science that the basis of taxation should be the alcohol they contain, not the bulk in which it is contained.

And further, in all stages of the production, sale, consumption, import or export, or what not, of alcoholic liquors, the taxation, licence duty, or whatever it be, should be upon the quantity of alcohol involved. Until that simple and palpably just and scientific basis is adopted, which will be when the State discovers that alcohol is a definite chemical reality, the tendency will always be to favour the production and use of alcohol in powerful rather than in weak concentration. No doctor, physiologist, sociologist, or other student of the subject, however they may differ otherwise, will be found to question the assertion that this is precisely the tendency which we wish to avoid. The State would not lose by grasping the idea of alcohol as an entity and acting upon it, and everyone else would gain.

The Various Forms of Alcohol and the Problems They Raise

It is this definite entity, found in various proportions in various fluids, that we are here discussing, and we have now stated its chemistry and have traced the various fates of a dose of it administered to the body. We have seen that in part it is oxidised, though whether that part is wholly or at all oxidised *completely* no one yet knows, the probabilities being against that supposition; and that in part it is excreted, primarily by the chief organs of excretion, and secondarily by any others that may be available, such as the breasts of a nursing mother.

We must now proceed to discuss its action within and upon the body in health and disease. But this chapter may conclude with brief reference to a third member of the series of alcohols, of which we saw that the first was called methyl alcohol, and the second ethyl alcohol. A somewhat later member of the series is known as amyl alcohol, or, in its crude state, as fusel oil. It has a very definite physiological importance, especially in Scotland, Ireland, Africa, and other parts of the world where raw, crude spirits are at all largely consumed. The process of formation of spirits from grapes, cereals or potatoes is very complicated, the fermenting material being extremely complex to start with. Many alcohols and ethers and other bodies are

formed. Many of these are highly offensive; and the process of maturing whisky and brandy, etc., depends upon the gradual removal or destruction of such substances. Amyl alcohol is far the most important, having a directly deliriant action upon the brain. Anyone who has any experience of its results in violent crime, and in the immediate misery not least of the drinker himself, will agree that the sale of raw spirits containing a large quantity of amyl alcohol should be made illegal. It would not be difficult to fix a standard, so that a certain given percentage of amyl alcohol should not occur in any spirits sold; and such a regulation could certainly do no injury to those interested in the sale of spirits as a whole.

Ill Effects of Alcohol Due to the Drug, not to Anything Combined with It

We insist upon the important characteristics of this particular impurity because its presence naturally opens the way to an interesting argument in defence of alcoholic liquors when their ill effects are commented upon. The argument is that those ill effects are due to the pernicious impurities contained in cheap and nasty alcoholic liquors, to which those sold by the apologist in question doubtless form so conspicuous an exception. Hence the cry arises for good and pure liquors, and alcohol itself is relieved from the odium cast upon it. We have seen how the special deliriant, infuriating, maddening properties of amyl alcohol support this contention. For the rest, there is nothing in it. The results described as following the administration of alcoholic liquors in general have been proved to be due to the alcohol; and anyone may destroy himself or others as easily with one as with another, according to the actual quantity of alcohol that it contains.

The Obvious Effects of Alcohol in Producing Nervous Disease

All over the world, and in all times of which we have record, men have fermented sugar for the sake of the alcohol. The name of the resulting drinks is legion, even if we only count those in present use alone. In all these cases, the alcohol is what matters; and it need hardly be said that all the necessary scientific experiments have been made and repeated with pure solutions of alcohol and water, so as to have established this point far beyond question. By all means let alcoholic liquors be pure, but they will retain all their characteristic properties so long as and in proportion as they are alcoholic. The tragic fashion in which men habitually do less than justice to their intelligence and honesty on this of all subjects was never better illustrated than in the famous scare about arsenical poisoning from beer, not many years ago, when large numbers of cases of arsenical neuritis were recorded, following on the consumption of beer made with sugar which had contained traces of arsenic. But no one who has worked for a week in a general hospital is unfamiliar with the alcoholic neuritis which is caused by beer every day, and which is the most characteristic and frequent nervous disease produced by alcohol. In the famous Northern scare about arsenical beer, probably hosts of ordinary cases of alcoholic neuritis, such as compete for admission to any general hospital, were put down to arsenic.

It finally should be said that alcoholic liquors contain no medicinal substance of any importance, other than alcohol itself, just as they contain no other deleterious substance of any importance, apart from the amyl alcohol in crude spirits.

Charlatan Superstitions that are Kept Alive to Screen Alcohol

If there are ill effects, the alcohol is responsible for them; if good effects are to be anticipated, it is charlatanry to attribute them to anything but the alcohol. No doubt there exists a kind of fashionable physician, a parasite upon parasites, who assures the idle and foolish in his consulting-room that such and such a wine is priceless on account of the "special ethers" it contains; but that is commerce or fraud, and science has no part in it. Nor has science anything to say to the long-standing superstition that certain of the pigments in wine have a subtle connection with the red pigment of the blood. The notion that a red wine will enrich the red blood, as a white wine would not, is ridiculous from the standpoint of science. What the action of alcohol really is upon the blood we shall see in due course. Meanwhile, we note that the red pigment of red wines has no more value in making red blood than red paint has. Indeed, while white wines are misnamed, being really colourless or pale yellow but never white, there is one really white fluid which never will have a rival in anæmia, for nothing makes red blood like white milk.

Having thus arrived at the often-contested but now well-established conclusion that, for good or for evil, what matters in alcoholic liquors is their alcohol, we may proceed to trace its action in detail.

HARNESSING THE WIND

Can the Cheapest and Largest Source of Power in the World be Used in Industry?

WHAT THE LATEST WIND-ENGINE IS DOING

If Lord Kelvin were still alive, he would be much interested in the machine-shop at the Government dockyard at Husun, in Germany. Above the shop is a windmill of apparently an old-fashioned type. It works under a very gentle breeze—too gentle a breeze to be of use in an ordinary windmill. Yet, out of this slight movement of the air, power is obtained to drive a twelve-foot engine lathe, a sharper, a blower for two forges, and a circular saw twenty inches in diameter. All these machines are driven at the same time and at full speed by the seemingly old-fashioned windmill with its four sails.

As a matter of fact, fifteen horse-power is obtained from the wind. And, far from being old-fashioned, the wind-engine is the latest development of long, arduous scientific research and surprising inventive genius. For seventeen years the Danish Government gave Professor P. La Cour the funds and the opportunity to carry out an exhaustive scientific study of windmills. From 1891 to 1908 he devoted all his genius and his energy to working out the idea of a new prime-mover. He was inspired by some remarks by Lord Kelvin which had excited the attention of some of the best minds throughout the civilised world.

Lord Kelvin's statement is worth reproducing, though it was made before certain kinds of explosive engines and internal-combustion engines were sufficiently perfected to alter the problem of the world's future supplies of fuel for prime-movers.

"When we look," said Lord Kelvin, "at the register of British shipping, and see 40,000 vessels, of which about 10,000 are steamers and 30,000 sailing-ships, and when we consider how vast an absolute amount of horse-power is developed by the engines of those steamers, and how considerable a proportion it forms of the whole horse-power taken from coal annually in the whole world; and when we consider the sailing-ships of other nations which must be reckoned in the account, and throw in the little item of windmills, we find that even in the present days of steam ascendency old-fashioned wind still supplies a large part of the energy used by man. The subterranean coal stores of the world are becoming exhausted, surely and not slowly, and the price of coal is upward bound. When the coal is all burned, or long before it is all burned, when there is so little of it left, and the mines from which that little is to be extracted are so distant and deep and hot that its price to the consumer is greatly higher than at present, it is most probable that windmills, or wind-motors in some form, will again be in the ascendant, and wind will do man's work on land at least in proportion comparable to its present doing of work at sea. Even now it is not chimerical to think of wind superseding coal in some places for a very important part of its duty—that of giving light. Indeed, now that we have dynamos and Faure's accumulator, the little wanting to let the thing be done is cheap windmills."

Wind is naturally the cheapest of all sources of power. The great coalfields are few in number, expensive to acquire, and costly to work. Oil-wells are still rarer. Even water-power is available in a large way only in regions combining a humid climate with an extensive and steep watershed, or at a vast waterfall. Niagaras and Victoria Falls, however, are remarkable for their scarcity, and there are not many countries with the advantages in stream-power that Norway and Switzerland possess. Sun-power, if we may judge by the results now being obtained with the Shuman solar-motor in Egypt, will be of general and

practical value only in the cloudless and burning skies of the tropics. In the temperate zones, the power of the mighty rivers of air incessantly sweeping over earth and sea are the commonest, freest, and vastest fountain of energy that can be made use of. They do not freeze in winter, like some of the Norway supplies of water-power; they do not need vast reservoirs; they are not exhaustible, like coalfields and oil-wells; they are free, universal, and eternal.


A VISTA IN HOLLAND, WITH WINDMILLS IN LINE ON THE HORIZON

The modern civilised man is scarcely in a position to appreciate the enormous amount of wind-power that is wastefully playing about him. If he is a city-dweller, he lives for the greater part of his life within walls, and in his short daily walks he is sheltered by ramparts of brick and mortar. Even the homes of country folk are usually set at the bottom of the hills, and thick hedges and rows of trees protect their fields and gardens from the gale. Thus the conditions of our lives tend to protect us from the natural force of the moving air. We notice it when it has the speed of an express railway train; but the gentle, continual sweep of steady, usable power that it maintains, above our heads, for 6182 hours out of the 8760 hours of the year, escapes our attention. For three quarters of the year the wind is moving above us at the rate of ten miles an hour. This used to be the lowest working-power for a windmill, but a wind at six and a half miles can be changed into light, or into machine work, by the new Danish wind-motor.


WINDMILLS BESIDE A CANAL IN HOLLAND

A hundred years ago, the whole of the milling, stamping, sawing, and drainage of our Eastern Counties was done by the breezes of the heavens. It is not impossible that our East Anglians were the original inventors of the windmill, for the mill built by Dean Herbert on his glebe lands at Bury St. Edmunds in 1191 is the first thing of the kind of which there remains any historical evidence. By a happy chance it excited the wrath of Abbot Samson, as it interfered with his abbey mill, so the incident is recorded in the famous chronicle of Jocelin of Brakelond. What use the Dutchmen of the fifteenth century made of wind-power need not be explained at length. By means of an improved windmill they pumped a large part of their country out of the sea. All the western provinces of Holland are below sea-level, and have been painfully won, and laboriously maintained, by means of pumps worked by the Dutch mill.

In 1750 an important advance in the use of wind-power was made by Andrew Meikle. This ingenious Scotchman made the Dutch mill automatic in working, by setting a small rotating fan at right angles to the principal sails. The result was that when the direction of the wind changed it was no longer necessary to twist the top of the mill round by a long pole. The fan did all the work. Offering its surface to the wind, it was twisted round, and, as it moved, the top of the mill moved with it. It stopped when it had so shifted that it only presented its edge to the breeze; and when it was in this position the large sails of the windmill were brought into play and set whirling by the full force of the rushing air.

At the beginning of the nineteenth century Sir William Cubitt perfected the old-fashioned mill by making it reef its

A TYPICAL WINDMILL AND SCENE NEAR AMSTERDAM, IN THE LAND MADE BY THE MILL

sails when the wind became too violent. This he accomplished by constructing the sails of wooden laths, corded together in the manner of a Venetian blind. In a storm the wooden laths turned edgewise to the wind. So, instead of the sails revolving too quickly, they slackened their speed, and prevented any damage being done to the grinding machinery.

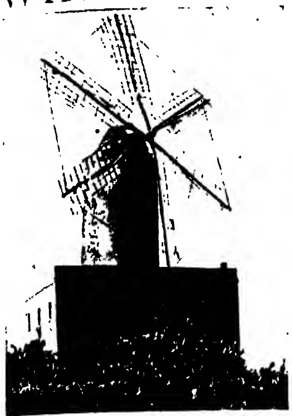
The windmill thus became a sound and automatic prime-mover just at the time when the modern steam-engine was being developed into the grand source of power in modern civilisation. During the last hundred years it has seemed as though the wind-engine arrived too late to be of much service to mankind. It had a great defect. Working only with a wind blowing at the rate of ten miles an hour, it was often idle just when power was most urgently required. It could never be depended on. So, in spite of the fact that it was the cheapest of all motors, the windmill was soon displaced by the more expensive but more trustworthy steam-engine. Even in Holland the picturesque and economical windmill has often vanished or fallen into ruin; and the chimney-stacks of pumping-engines now dominate the low, flat land which the industrious Dutchman is still recovering from the destroying sea. In England, the steam roller-mill performs most of the work done by the old wind-engine; and in places where steam is too costly and cumbersome a source of power the gas and oil engine make the manufacturer independent of the changeable and irregular energy of the air.

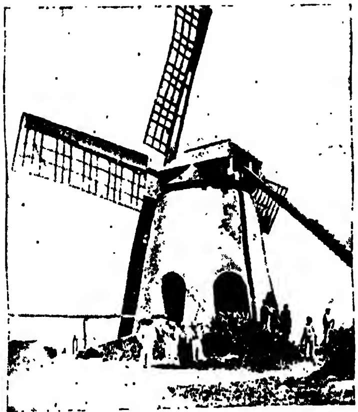
The Americans were the first people to see that the wind-engine was still a very serviceable force in modern civilisation. About the middle of the nineteenth century one of their inventors, John Burnham, devised the American mill. This is a very light and cheap machine, that will work in a five-mile wind. It consists of a small fan erected on the top of a tower of steel lattice-work with a concrete foundation. The fan is made of a number of small sails of galvanised iron; sometimes as many as a hundred sails are fixed in a double ring round the wheel. But, as a rule, the American mill is from ten to twelve feet in diameter, with eighteen or more metal sails. Straight from the back of the fan projects a well-balanced metal vane. This acts in the same way as Meikle's device. It veers round with the wind, turning the top of the mill with it, and setting the larger wheel against the current of air.

HOW WIND-POWER IS UTILISED ON THE MODERN FARMS IN NEBRASKA

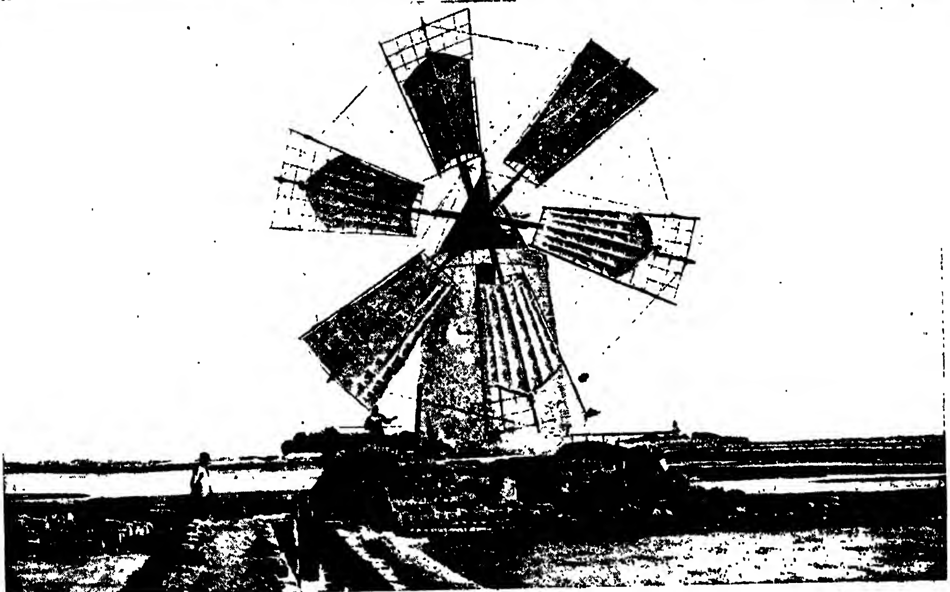
As the best mills are mounted on roller bearings, the force necessary to turn them is very small. So the tail vane is also small. These mills have played an important part in the agricultural development of Western America, the Argentine, and Australia. Indeed, without them many large tracts of waterless land in the world would still be sterile and uninhabited wastes. For instance, there is abundant

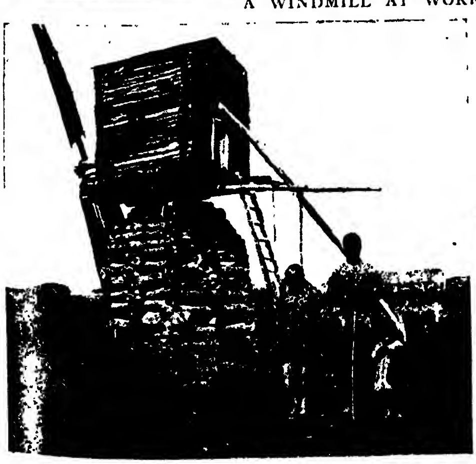
WINDMILLS FROM MANY COUNTRIES


A TYPICAL MALTESE MILL


SUGAR ESTATE MILL IN ANTIGUA


A MILL IN CERIGO, GREECE


A WINDMILL AT WORK IN TRAPANI, ITALY


WIND-POWER IN SIBERIA


A WINDMILL IN ATTICA, 250 YEARS OLD

X

water in Nebraska, but it is too deep below the surface to nourish any crops, and scarcely any rain falls. Yet in the valleys a strong wind sweeps along for nine days out of ten. So the farmers have harnessed this mighty force of air to their pumps by means of light, cheap, metal mills. They have made the wind irrigate an apparently hopeless desert, which is now transformed into a green and fertile expanse of corn-land. Besides pumping up water, the mills grind the grain and cut fodder for the cattle, and produce electric light.

Very ingenious is the manner in which the irregular power of the wind is converted into a regular supply of electricity. An ordinary small pumping-mill is used, and the water is pumped into a reservoir situated in the basement of the farmhouse. The reservoir consists of a cylinder in which the water is kept pressed down by a heavily weighted plunger. By this means the water in the cylinder is maintained at a pressure of seventy-five pounds to the square inch. When this force has been attained, the plunger rises and strikes a catch which opens a valve. The water then runs into a water-wheel, and the whirling water-wheel works a dynamo, and so generates sufficient electricity to light twenty electric lamps. Any excess of current is saved in a small storage battery. The battery consists of eleven cells, and it can store sufficient current to light the farm and outbuildings for a week. But as the mill works at least five hours every day in light winds it is very seldom that the stored electricity is needed any length of time.


SOERENSEN, DANISH IMPROVER OF WINDMILLS

The American mill, however, now seems to be doomed. It is cheap and light-running and easy to start, but it is not scientific. Such was the conclusion at which Professor La Cour arrived after seventeen years of research and experiment. The great Danish man of science entered on his study of windmills for national reasons. Both in Denmark and in Northern Germany the absence of large coalfields has seriously impeded the development of industries; and for years the Danes and the Germans have been searching for new sources of power. Possessing no swift, strong streams of falling water that could be converted by modern methods into electrical energy, they have had to discover new fields of power. One of the magnificent results is that Germany has produced a brilliant line of inventors of gas and oil engines; and their fine achievements have been crowned by a remarkable discovery in regard to potatoes, made by some German industrial chemists. These ingenious men now use the potato for the production of alcohol, and succeed in getting from it a very cheap spirit that can be employed to drive an engine. At the present time the alcohol-engine is cheaper to run than a petrol motor; and it is very likely that potato-spirit will prove to be an important and permanent addition to the power resources of mankind. Already it is the main factor in Germany in keeping down the price of petrol. It will be obtainable in abundance in the distant future, when the last-known oil-well is exhausted and the last-known coalfield is emptied of its black treasure.

The Danes were apparently less enterprising than the Germans in the quest for new sources of power. But their researches and experiments may yet acquire a value higher than that of the achievements of Otto, Diesel, and the industrial chemists who exalted the humble potato-field above the oil-well and the coal-mine. For the Danish Government, by backing Professor La Cour, has performed an immense service to mankind in general. It is true that Professor La Cour died in 1908, before his work was completed, but other Danish men of science are building on the foundations he laid.

Following out the idea of Lord Kelvin, La Cour tried to discover a way of connecting

TWO TYPES OF WINDMILL SIDE BY SIDE AT OUTWOOD, SURREY

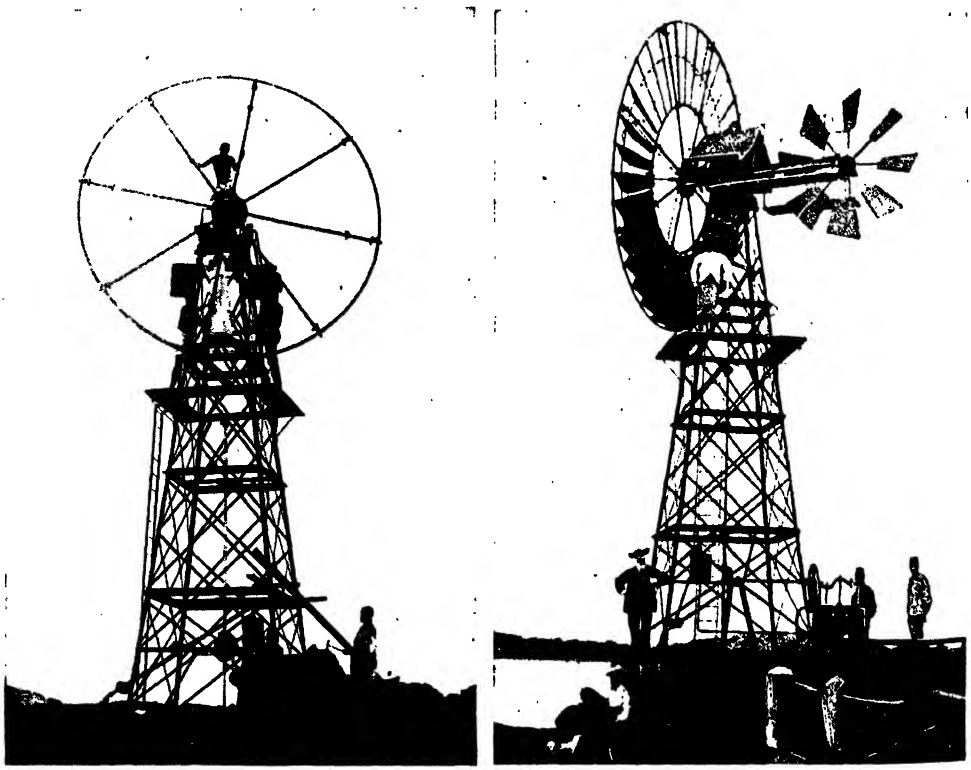
A WINDMILL AT LYTHAM

A WINDMILL AT UPMINSTER

a windmill to an electric dynamo and an electric accumulator, so that a reservoir of energy should be formed. The only thing that prevents the wind-engine from competing with steam and gas and oil engines is its irregularity in working. It is useful in irrigation work, where the pumping can be done at any odd time, but it is disastrously inconvenient in a modern workshop. On a windless day it stands idle, and the men depending on it for power to drive machinery are unable to get on with their work. They are in the doldrums. Meanwhile, rent and wages and the interest on the capital costs of the wind-engine are mounting up. But before trying to solve the chief problem in the use of wind-power, La Cour resolved to work out by experiment the principles of windmill construction. He used a large number of models, set in motion by the wind from an electric fan. This enabled him to change and regulate the wind-force in whatever way he wished. Naturally, he began with mills of the American pattern. The results were depressing. Very little of the force created by the electric fan and communicated to the air was recovered by the latest and most improved form of wind-engine.

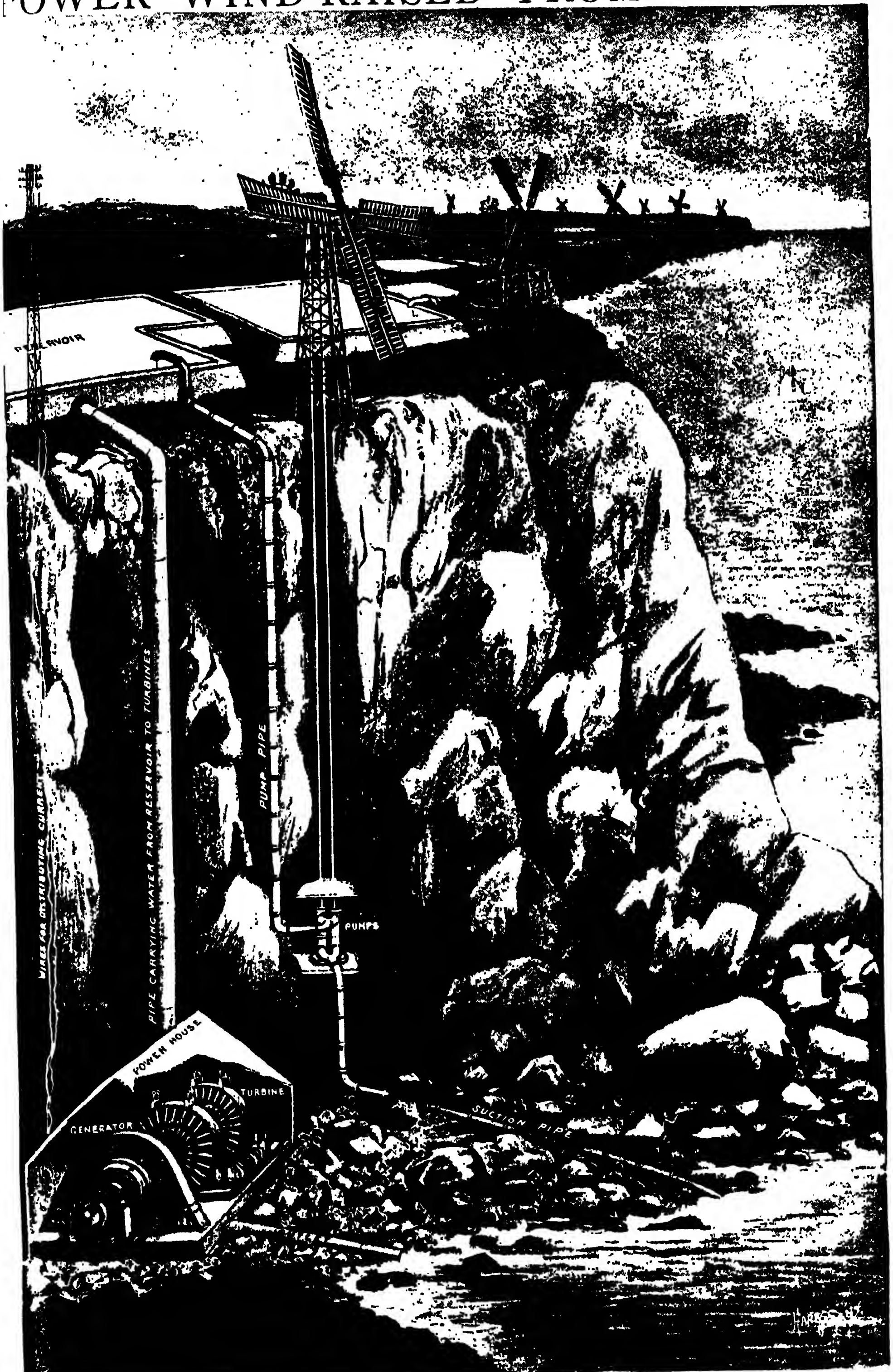
One would have thought that by fixing to a wheel as many sails as it could carry more power would be obtained from the wind. A modern five-masted sailing-ship uses considerably more than an acre of canvas in order to catch as much wind as possible, and so increase her speed. The Americans had revolutionised the merchant marine of the whole world by building clippers faster in motion than the ships of any other nation. Forty British shipbuilders were bankrupted owing to the inventive enterprise of the American designers. This happened towards the middle of the nineteenth century, just when Burnham was thinking out the construction of the American mill. Naturally, he went by the results of the clipper design. He made his wind-engine a light and racing kind of craft, and crowded on it all the canvas it would bear. Later designers improved on his ideas, until mills were built with a hundred sails arranged on a wheel $37\frac{1}{2}$ feet in diameter.

Professor La Cour showed that this was all wrong. It turned out that our ancestors of the twelfth century were in advance of the cleverest of American mill inventors. In other words, more power was obtained from



THE ERECTION OF THE FIRST WINDMILL IN UGANDA BY NATIVE LABOUR

POWER WIND-RAISED FROM THE SEA



IT HAS BEEN SUGGESTED THAT, BY SUCH MEANS AS ARE ILLUSTRATED ABOVE, VARIABLE WIND-POWER MIGHT BE STORED IN RAISED WATER, WHICH COULD BE USED TO GENERATE ELECTRICITY

a mill set with four sails in the old fashion than from a wind-motor with a large number of metal sheets fastened to a wheel. The wind-engine works on a different principle from the sailing-ship. Too many sails break and scatter the force of the moving air; and, as the Danish man of science proved, a series of large spaces is necessary between the arms of a windmill in order to allow the wind to exert its full strength. So it comes that the scientific windmill built by Professor La Cour at his experimental station at Askov has four arms, in the old and picturesque manner. There is, indeed, very little difference at first glance between the Askov wind-engine and the Sussex windmills that still work at a profit, grinding oats for poultry-farmers. The four sails, however, are very cleverly worked by a system of rods and levers that alter the Venetian-blind-like slats, with automatic exactitude, in answer to the varying power of the wind. The four arms are about 7½ yards long and 2½ yards wide. Thus the sail area is scarcely eighty-eight square yards, yet the power derived from it is sufficient to drive two twelve horse-power dynamos for the generation of electricity.

WINDMILLS WITH FIXED VANES

On the left is an eight-foot windmill on a thirty-foot tower; on the right a twenty-foot windmill on a forty-foot tower. The lofty cranes are used in their erection.

Professor La Cour had everything that a man of science needs, except one thing. He had the generous help of the Danish Government, and he possessed himself a large fund of knowledge, a high engineering skill, and an unconquerable quality of perseverance. He would give months to working out a single problem, and if he obtained a negative result he was well pleased with it. It was good, useful knowledge, and it enabled him to point out to other experimenters the blind alleys that were to be met with in the long and difficult search after a cheap and universal source of power. What the professor lacked was the inspiration of genius. But this was supplied a few years before his death by a young Danish inventor, Soerensen, who came to him with a small model of a new kind of wind-engine. Soerensen had built on La Cour's researches. His windmill had only four arms, but the curious point about it was that these arms were curved. Soerensen called his contrivance a conical wind-motor. Professor La Cour tested it against two of the very best of German wind-engines. He found that, though the sail area was only one-seventh that of the German motors, it developed 50 per cent. more power!

The Soerensen motor can work with a current of air that is just perceptible. But, of course, it produces more power when it is set in motion by a steady breeze. In Germany and Denmark it is found more profitable to build wind-engines with very large sails, and adjust the machinery to a light current of air, moving between six and eight miles an hour. This is a low wind-rating, in which considerable power is sacrificed to regularity in working. Yet by means of it a fifty horse-power wheel, used for electric lighting and general power-production, can be kept running with only thirty idle days in the year. The town of Wittkeil, in Schleswig, is lighted by a thirty horse-power wheel, working with a wind-rating of eight miles an hour. All the electrical machinery is adjusted to this speed. So when the wind grows stronger the sails partly open, and allow the excess of power to pass through unused.

This would be a great waste in a wind-engine erected on our Atlantic coast, where there is a steady and trustworthy breeze

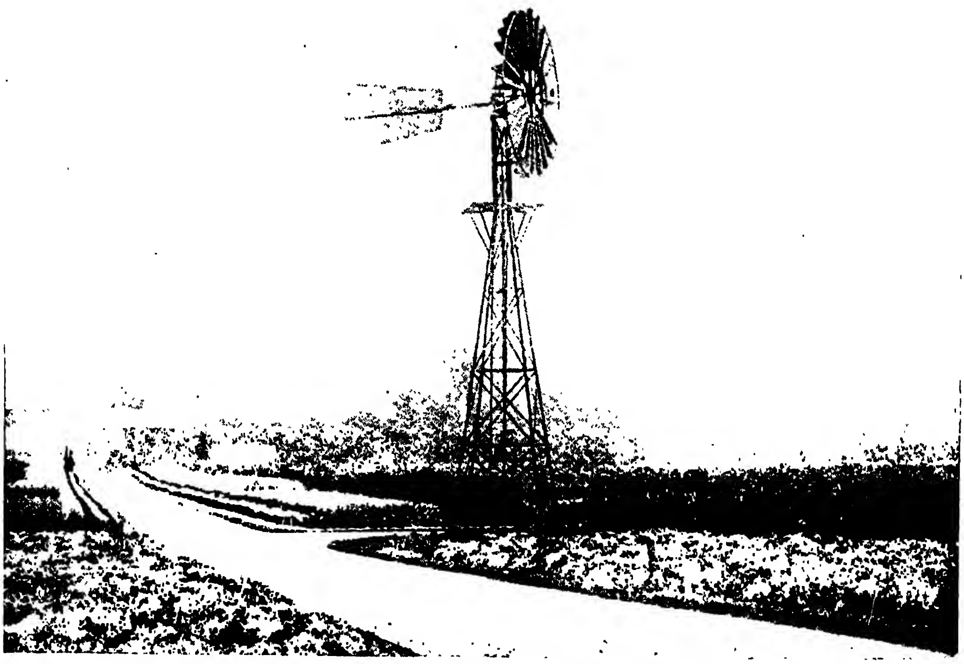
WIND-WORKED SHIPS AT SEA AND AT REST

THE UPPER PICTURE SHOWS THE GIGANTIC "PREUSSEN" WITH ALL SAILS SET, AND THE LOWER PICTURE THE SAILING-VESSELS IN HAMBURG HARBOUR

with a speed of ten miles an hour. It would be throwing power away to regulate a wind-engine on our Western shores to a slight breeze that is just perceptible. But in Continental districts, where there is only a light, regular movement of the air, the wind-motor must be specially constructed to bring in a small but constant income of energy. To increase this income it is necessary to enlarge the size of the four or six sails. Every foot square of the sail surface of a scientific wind-engine yields an amount of work equal to the energy expended by a horse in lifting a pound weight about the fourth of an inch from the ground.

Northern Germany. In most cases these expensive wind-plants have been put up by State or municipal enterprise. But a private German firm at Kiel is now very busy constructing Soerensen motors, and selling them to private purchasers.

We do not know if any British mill-wrights have yet abandoned the American mill for the curved or grooved Danish wind-engine. If this has not yet been done, there is a magnificent opening for some enterprising millmaker well acquainted with the results of La Cour's researches, for a scientific British-worked mill of considerable power would be cheaper



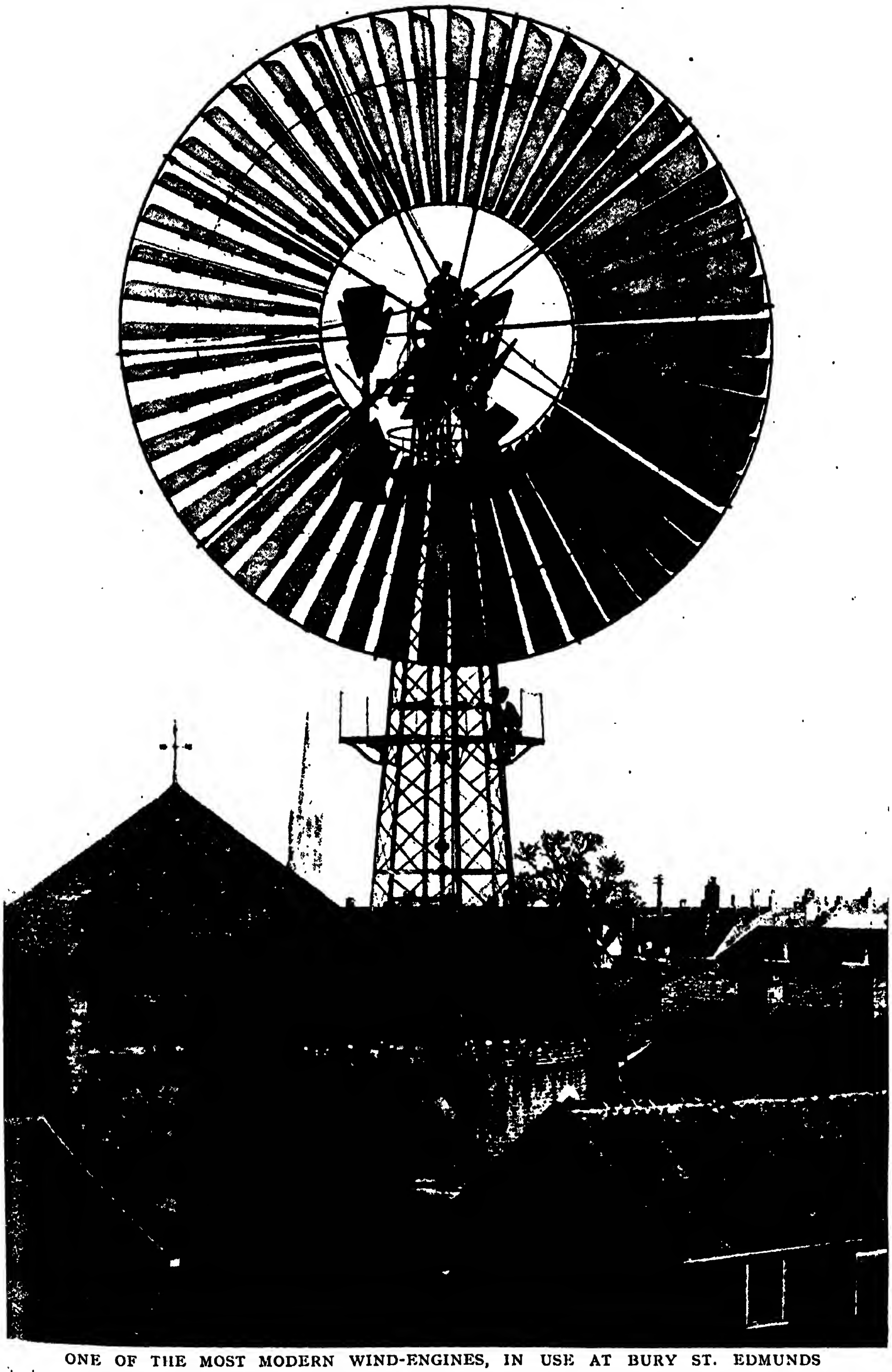
A WINDMILL EMPLOYED FOR RAISING WATER ON A FAMOUS NURSERY

But to get this result the wings must be curved. For a curved wing develops nearly twice as much power as a flat wing. It has been found, however, that if the wings are grooved they possess the same capacity for catching and holding the force of the air as curved wings have. And as it is more convenient to use straight but grooved wings, the Danish Government has adopted the grooved form in their recent experimental work. It is by doubling the size of a sail of the curved or grooved sort that double the amount of power is obtained. Thus it has come about that huge windmills, costing £900 to build and fit, have sprung up in Denmark and

than the wind-engines now coming into general use around the Baltic. For while doubling the sail-surface only doubles the power of the mill, doubling the wind-rating trebles the amount of energy derived from the moving air. It is thus a very great advantage to set the new wind-engine running at the working speed of our old-fashioned windmills, which is ten miles an hour. Apparently this cannot be done with profit in Germany and Denmark, but high speed and regularity could be combined in our breezy island kingdom.

We are excellently served in regard to wind-power. Strong streams of falling water are not abundant in our islands

ENGLISH WIND-ENGINE FOR PUMPING



ONE OF THE MOST MODERN WIND-ENGINES, IN USE AT BURY ST. EDMUNDS

Photographs on these pages are by courtesy of Mr. Wallis Titt, Messrs. R. Warner & Co., Messrs. Merryweather & Co., A. K. Williams & Co., Messrs. Sutton & Sons, Frith, Underwood & Underwood, and others. The above is Mr. J. W. Titt's "Simplex."

except in the Scottish Highlands; and even there it is probable that the freezing of the smaller streams in winter would interfere with the regularity of the new power-supply. It is in winter that power for lighting is needed in large and regular quantity, and it is here that the new wind-engine is exceptionally useful. By a happy coincidence, the coldness of the atmosphere leads to an increased energy of movement in the currents of the air. For, when other things are equal, the denser the air becomes, the greater grows its pressure. So a cold winter will produce much more wind-power than a warm summer climate. If wind-engines were largely used in our country for the generation of electric light it might be possible for some of our brilliant engineers to devise a mill which would run on a light load in the warm summer months, and then alter its wind-rating as the days shortened and stiff, cold winter breezes began to prevail.

In regard to the average power that could be obtained from a Danish mill in our islands, measurements taken at the Greenwich Observatory show that, at a height of 211 feet, a ten-mile wind is blowing during the greater part of the year. Hills with a height of 625 feet are still more favoured, and on mountains like Ben Nevis there is an absolutely regular movement of air. And we have already seen that on the Atlantic coast there is a very steady breeze which can easily be turned into a free, cheap, and general source of power. Our position on the edge of the Atlantic, with the Gulf Stream constantly changing the temperature and altering the density of the air, is singularly happy in regard to the working of wind-engines. And our Eastern Counties have a broad stretch of sea between them and the Continent of Europe which also acts as a continual wind-raiser.

Thus the work that has recently been done in Denmark has a special importance for us. Several villages in Denmark and Northern Germany now use wind-motors for pumping up the general water supply, and for making the electric current used in public lighting, and Government dockyards and private workshops obtain from the wind the power that drives all their machinery. One wind-motor recently erected in Germany cost 18,000 marks. This was 7000 marks dearer than a gas-engine of the same power. The wind-motor, however, has no fuel expenses, and the consequence is that it earns a dividend of 12 per cent. It is a striking figure, and both the Danes and the Northern Germans have been impressed by it. So for some years past they have been erecting wind-motors that develop in a light breeze the power of thirty to fifty horses.

As a rule, no attempt is made to store up energy in order to get over the periods of calm, windless weather. For Professor La Cour did not succeed in devising a cheap and practical way of saving up the power of the new mill. At his experimental station he used the ordinary storage battery. But this had already been done by Mr. George Cadbury in England and Mr. Brush in America, both of whom were inspired, like Professor La Cour, by the statement of Lord Kelvin. La Cour's wind-engine was, of course, more scientific in design and economical in working than the modern mills used by the English and American experimenters. Yet, as the Dane did not discover a new and better means of storing the power of the wind, he cannot be said to have solved the all-important problem of the wind-engine. And it is very doubtful if anything can be done in the absence of the electrical accumulator for which all the world is anxiously waiting.


THE HEAD-GEARING TO WHICH THE VANES ARE ATTACHED

It is true that the wind-engine can be made to pump up water into a reservoir on a hillside, from which the water can be conducted into an electrical generator. But the cost of building such a reservoir is too great for ordinary purposes. Some engineers have designed an air-compressing plant that could be worked by a wind-motor. In this case the tank of compressed air could be used to drive machinery

whenever the wind failed. But the trouble is that the cost of the storage tank and of the heavy and powerful compressed-air plant is so great that it is more convenient and less adventurous to purchase a suction gas or crude oil engine. The fact is that the inventions of suction gas-plant, and of oil-motors using tar-oil and petroleum waste, have so cheapened power production in many countries that the wind-engine has a much harder fight before it than it would have had in the days when the steam-engine was without a serious rival.

Yet the still despised windmill is already doing better work than most small prime-movers. For it has found a temporary yet successful means of paying its way. Put up cheaply to run with the lightest breeze, it works practically all the time it is needed; and when by chance the wind fails, a small gas-engine continues its labours. The double cost of installing both a gas and a wind motor is soon covered by the saving in fuel. A few gallons of oil or alcohol, or a few thousand feet of gas, are all that is needed to combine extraordinary cheapness of power production with machine-like regularity in working. In practice, this scheme has been found less expensive and much less troublesome than any kind of storage system.

A FORTY-FOOT WINDMILL WITH SELF-FEATHERING VANES AND GEARED HEAD

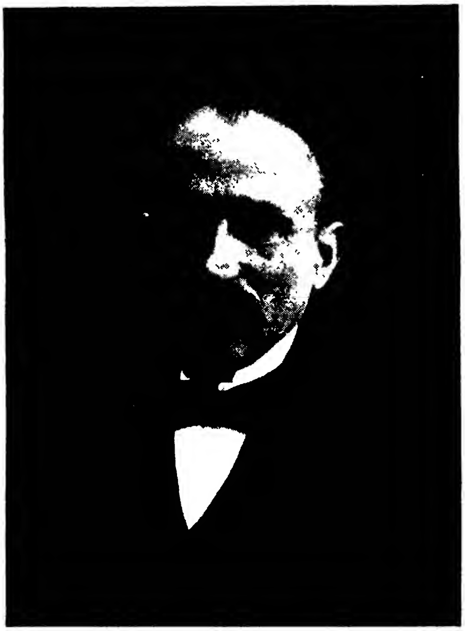
Yet Professor La Cour's idea of linking the new windmill through a dynamo to an electrical accumulator may yet prove to be the best. For another Danish man of science, Professor Hannover, of Copenhagen, has been working for some years on a new electrical invention which may revolutionise other things besides windmills. After five years of experiments he has made an accumulator which has four to five times the capacity of any similar means of storing up electrical power. It consists of a sheet of lead, possessing millions of very minute pores. The pores are smaller than the point of the very finest needle that it is possible to make. Some accumulators of the new pore-metal have been used for the last six months by the Danish State Railway; and all this time the electrical energy has lasted, without any re-charging—from four to five times as long as that in any other accumulator.

There are many branches of electrical engineering in which this invention will effect a great saving in cost, and in some businesses it will turn a loss of money into a good profit. So it is not unlikely that the dream of Lord Kelvin and the work of La Cour will soon be realised by an accumlator of pore-metal attached to a dynamo worked by a wind-engine. In this case there will be a remarkable revival of village industries, and our breezy uplands will be adorned with the picturesque wind-motor, its four arms outspread to the breeze, and singing to the little hamlet of industry scattered about in the watercourse below.

It was the use of wind-power and water power in the old-fashioned windmills and water-mills that kept a very large amount of of our industries scattered about the country-

side in the eighteenth century. In the old days many small holders were able to contribute to the industrial wealth of the country; for they not only possessed an allotment of fruitful earth, but they lived near the sources of mechanical power. The great cities were mainly centres of commerce, and nearly all the productive labour was carried on in small country towns, villages, and hamlets. The countryman will not, for many generations, recover the industrial position which he lost when the heavy steam-engine and the railway broke up the village crafts, and created the huge industrial town. Yet the new wind-engine will help to repopulate our empty country-side. For it cannot be worked efficiently where there are innumerable buildings interfering with the broad-flowing currents of the air.

There is no need to set the new wind-motor on a bare hill-top, though this is sometimes very convenient. It saves the expense of putting up a light steel framework, and it lifts the mill clear of trees and houses. But a lattice tower of steel or iron can now be built at a comparatively small cost; and there are already many mill-makers who specialise in these structures, and manufacture them very cheaply in standard patterns. So even now it does not cost much to run up a tower that will set an ordinary mill high enough to catch a fairly good wind. With an improved Danish mill, farmers would obtain a cheap supply of power, enabling them to save a good deal of expense in various ways. With larger mills, such as those used in foreign dockyards, an enterprising village mechanic could start a power workshop that would give employment to some of his poorer neighbours.



PROFESSOR HANNOVER, OF COPENHAGEN

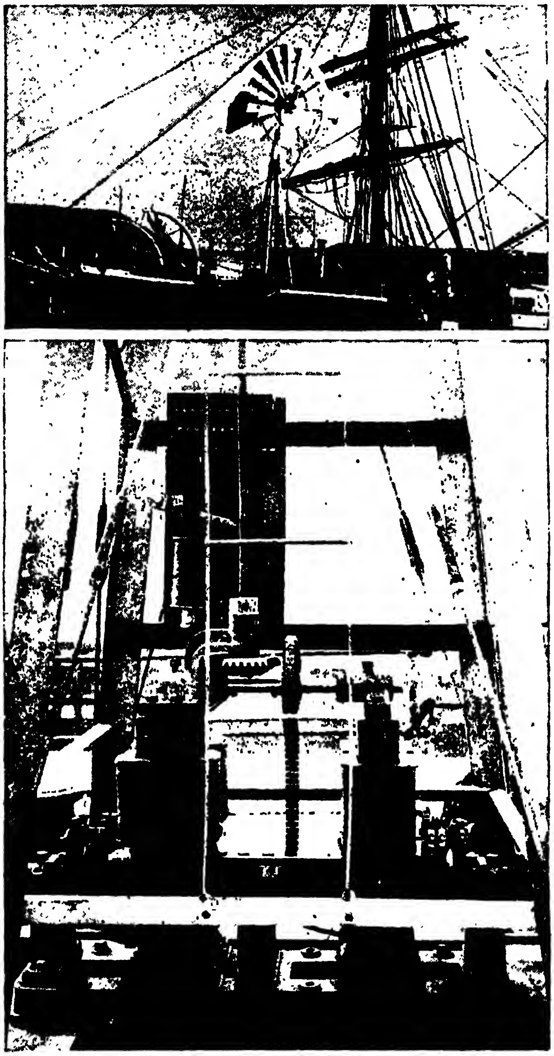
There are still some textile crafts that could be recovered from the great weaving towns by means of a wind-engine that was quite regular in its working; and innumerable other fields of industry would be reopened to members of village communities happily situated with regard to the mighty forces sweeping in invisible lines over the broad earth. Even with the Danish mill in its present form, a small holder who divided his time between his fields and his little power-house ought to be able to make a good profit out of his labours. Certainly there are many villages and small towns that could run a public lighting service and a general water-supply by means of the new motors. For both of these things are now done by wind-power in various places on the Continent.

It would also be easy to light great passenger liners with the wasted wind they create as they plough their way through the waves. Captain Scott, indeed, fitted a windmill on the "Discovery," when he set out on his first voyage of exploration in the Antarctic regions. The windmill was arranged to drive an electric-lighting plant, with a view to saving the small and valuable store of fuel. Unfortunately, the mill then used came to grief in a Polar blizzard. Certainly it should not be difficult to design a wind-motor, on the principle of Professor La Cour's discoveries, which would light any large ship with the wind produced by its speed. The engine would be simple and cheap to construct, for the forward movement of the ship would keep it running as regularly as clockwork. And if the new accumulator of pore-metal were used, the ship could be lighted in harbour with the wind that she raised on the voyage. And, being small, the motor would not appreciably increase the force needed to drive the vessel against air and water.

Of course, the windmill of the twelfth century is not the first instrument that man designed to make use of the power of the wind. There are sailing ships of the present day, built of steel and covered with acres of canvas suspended from five steel masts, which travel at an average speed of eleven knots an hour from the Old World to the

New. Probably it was some European of genius, living on the edge of the Mediterranean in the Stone Age, who first hoisted a sail to a pole on his little boat, and saved himself the labour of paddling down a river or across a bay. The Egyptians, eight thousand years ago, had sailing-boats, which they gradually developed into sailing-ships; and it is very likely that the earliest sea kings of Crete were even more advanced than the Egyptians in the art of navigating by means of wind-power.

The winds of the Mediterranean, however, are too uncertain and irregular for sailing-ships of a large kind. As a rule, it was necessary to use oars as well as sails on long voyages over the inland sea. The Greek warship, with its three banks of oars, became the handiest vessel in the ancient struggle for the dominion of the waves. It was not until new civilisations rose on the edge of the windy Atlantic that man began to build great ships, swifter and larger and steadier than any yet known, and impelled entirely by the forces of the air. Skill in shipbuilding and knowledge of seamanship then developed; and as the Middle Ages came to a close, man acquired so great an art in making use of the power of the wind that he was able to move around the world on the wings of the breeze, and discover vast new continents, which he began to people simply by getting power out of the movements of the air.



AN EXPERIMENT IN LIGHTING BY WIND-POWER
The windmill and the dynamo coupled to it for generating electric current for lighting the s.s. "Discovery."

It was, after all, the sailing-ship that gave the white races dominion over the two Americas, South Africa, Australia, and New Zealand. India fell to a small group of merchant adventurers, who came from the ends of the earth, borne on the winds of the air. The British Empire was built up by means of wind-power, though in a different way from that in which Holland was largely constructed by means of windmills. So, when all is said and considered, the power that man won from the wind has been of greater historic importance than the work that he has since done by means of steam-power. And the sailing-ship, like the windmill, is not yet conquered. She began to disappear when the Suez Canal made it possible for steamers to go where a ship depending on the irregular forces of the wind could not follow.

But when the Panama Canal forms a water-bridge between the Atlantic and the Pacific Oceans, the great cargo sailing-ships, built of steel and full of labour-saving machinery, will resume somewhat of their old and high position on the seed of the earth. Like the new Danish windmill, they will be fitted with an auxiliary engine that will take them through the canals, and help them to get over the doldrums. In the meantime, the wind-engine on land may develop into a generator of electrical power that can be stored up, cheaply and easily.

SUPPLIES FOR THE WORLD'S OLDEST INDUSTRY FROM THE WORLD'S OLDEST LAND

PREPARING WOOL FOR THE CARGO BOAT, ON THE BANKS OF THE NILE, WITHIN SIGHT OF CAIRO. BY FREDERICK GOODALL, R.A.

The photographs on these pages are by courtesy of the New South Wales Government, the Queensland Government, Messrs. Thomas Hardman & Sons Messrs. G. Leavey, and others

KEEPING MANKIND WARM

The Greatest Manufacture from Animal Products—the Woollen and Worsted Industries

WHERE YORKSHIRE LEADS THE WORLD

THE changing of wool into clothing, apart from its use when attached to the skin of the sheep, must have been the oldest industrial process for covering men from cold or wet. There are allusions to it in all ancient literatures; and we know that, quite early, men had acquired considerable skill in the methods of making wool into apparel. But though the business has been carried on for uncounted thousands of years, users of wool are not quite agreed upon a definition of wool itself—the basis of their manufacture. The difficulty is to distinguish between wool and hair. No one can tell where one ends and the other begins. Really, they begin and end on the same sheep, merging imperceptibly into each other. Wool is soft, curly, moist with a special oiliness, and covered with jagged scales; whereas hair, in these respects, is but a far-off imitation, passing into positive unlikeness. It is the serrated or jagged surface of the wool-fibre that gives it its peculiarity and its power of becoming interlocked and matted, or felted, and so serving as a warm protection in the form of clothing.

Wool is, broadly, either short and curly, or long and wavy rather than curly, and the distinction has led to a well-marked division in the manufacture, though that division is being narrowed constantly as time goes on. The short wool has been used for the making of cloth, and the long wool for the making of worsted; but increasingly, under modern machine-processes, the two kinds of wool are partly interchangeable for the making of the two different kinds of clothing—matted or threaded.

The sheep, the source of the wool, is one of the most widely distributed of animals, spreading over all the continents, and dividing into innumerable varieties. If, for example, we include all the ordinary varieties of sheep in the British Islands as one, and call it the "common sheep," the world can provide thirty-two kinds of sheep on that broad scale of division.

As the years have passed, and animal-culture has become better understood, the sheep has been developed greatly, both as a meat-producing and a wool-producing creature. It has been pointed out (in this work) that the development of the sheep by a Leicestershire grazier altered the whole course of British agriculture; and still two varieties of British sheep take a prominent position because of their size and the quantity of their wool. These are the Leicesters and the Lincolns. The first place, however, as a select wool-bearer has long been held, and is retained, because of quality, by the Spanish, or Merino, breed; and it is the Merino, with various crosses, that is providing the world with its finest wool from many lands.

There was a time, well within the range of recorded history, when England was a notable wool-exporting country, and the manufacture of woollen goods was chiefly carried on elsewhere. For hundreds of years the Flemings, in what is now Northern Belgium, with Bruges and Ghent as their chief centres, were the masters of the secrets of the manufacture; and not once, but over and over again, covering a space of three centuries, parties of them were invited to this country to establish their craft here. They came at intervals, a succession of minor immigrations, and, intermixed with Walloons from the more southern parts of Belgium, began the cloth trade of Yorkshire and the West of England, and more particularly the trade of Norfolk.

For several generations Norwich was the chief English centre of the woollen manufacture, and it only lost its pre-eminence by clinging to old-fashioned ways too long, and failing to adapt itself to new and

A FLOCK OF SHEEP IN A COUNTRY WITH NEARLY FIFTY MILLION SHEEP

A SCENE FROM THE RIVERINA DISTRICT OF NEW SOUTH WALES. A STATE WITH NEARLY FIFTY MILLION SHEEP, OR HALF THE TOTAL FLOCKS OF AUSTRALIA

revolutionary methods when the age of machinery arrived. The very name "worsted," which applies to something like one half of the trade, is derived from a Norfolk village in which a band of skilful Fleming weavers settled.

The turning-point in the evolution of the woollen manufacture came when Dr. Edmund Cartwright, a Leicestershire clergyman, showed the world how to comb wool by machinery instead of by hand. His invention, as perfected by later inventors and improvers, had the same effect on the output of woollen goods as Whitney's invention of the cotton-gin had on the cotton trade. It was impossible for a great manufacture to be carried on adequately for all the world when the material had to be handled laboriously by manual labour, as was the case in the days of hand-combing; but a whole series of events, happening more or less simultaneously, gave an enormous impetus to the woollen industry. Sir Joseph Banks set himself, with the energy of a scientific enthusiast, to spread the Merino breed throughout the world, and particularly in England and Australia, at a time when the development of machinery made an urgent demand for the wool. The result was seen in a growing supply, as the power to use the wool rapidly expanded.

EDMUND CARTWRIGHT, INVENTOR

HEILMANN, THE ALSATIAN INVENTOR OF A COMBING-MACHINE, CONCEIVING HIS IDEA WHILE WATCHING HIS DAUGHTERS AT THEIR TOILET

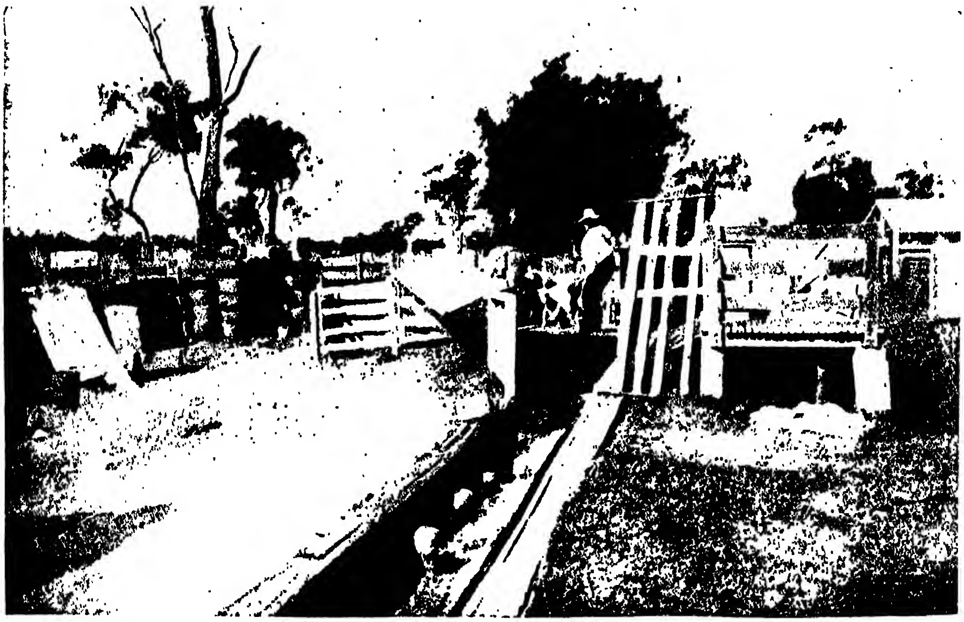
From the picture "Heilmann's Inspiration," by A. Elmore, R.A.

The coming of Cartwright into the world of wool-workers is one of the romances of industry. A Yorkshire man, educated at Oxford, he became a clergyman, addicted to minor poetry. With a living first in Derbyshire and then in Leicestershire, he was apparently one of the most unlikely men for such an enterprise as mechanical invention. In 1784 he went to Matlock, a place that was then much agitated by the disquieting inventions of Arkwright, who recently had been driven, with his new-fangled machines, from Lancashire into Derbyshire. At the dinner-table in the inn the Rev. Edmund Cartwright heard the argument that Arkwright's cotton-spinning machinery in the end must be an evil, for it would make more yarn than the weavers could use, and the outcome would be that the yarn would be sold abroad, and then would come back as manufactured goods to compete with English manufactures.

Cartwright met this argument with the suggestion that what was needed was the invention of weaving machinery, so that the weaving in England might keep pace with the spinning of the yarn—a theoretical view that was pooh-poohed firmly by the practical men present, who assured him that weaving by machinery was for ever impossible.

Cartwright was so convinced that he was right that he went home and set himself the task of inventing a power-loom. This he patented, and manufactured for himself, amidst public obloquy, and with financial loss. Then he undertook, as his second task in invention, to make a wool-combing machine—the first of its kind in the world. His machine was patented in April, 1790, and finally in May, 1792. It was named "Big Ben," and was worked by a horse turning a gin. It did not prove successful with the finer qualities of wool, but it established the principle on which trade pirates could, and did, make successful machines, though many years passed before combing by machinery was as good as combing by hand. Cartwright eventually received a Government grant of £10,000 for his invention of the power-loom, and died at the satisfactory age of eighty, after declaring spiritedly, in the last year of his life:

> With mind unwearied still will I engage,
> In spite of failing vigour and of age,
> Nor quit the conflict till I quit the stage.



DIPPING SHEEP AT JONDARYAN, QUEENSLAND, PREVIOUS TO THEIR SHEARING

Other inventors of wool-combing machines were James Noble (patent dated 1805), James Collier (1814), John Platt (1827), and George Edmund Donisthorpe (1843). The inventions and improvements by Mr. S. C. Lister (afterwards Lord Masham) and Isaac Holden bring us to within touch of the present day. A contemporary rival of Donisthorpe and Lister, and, later, Lister and Holden, was Josué Heilmann, an ingenious

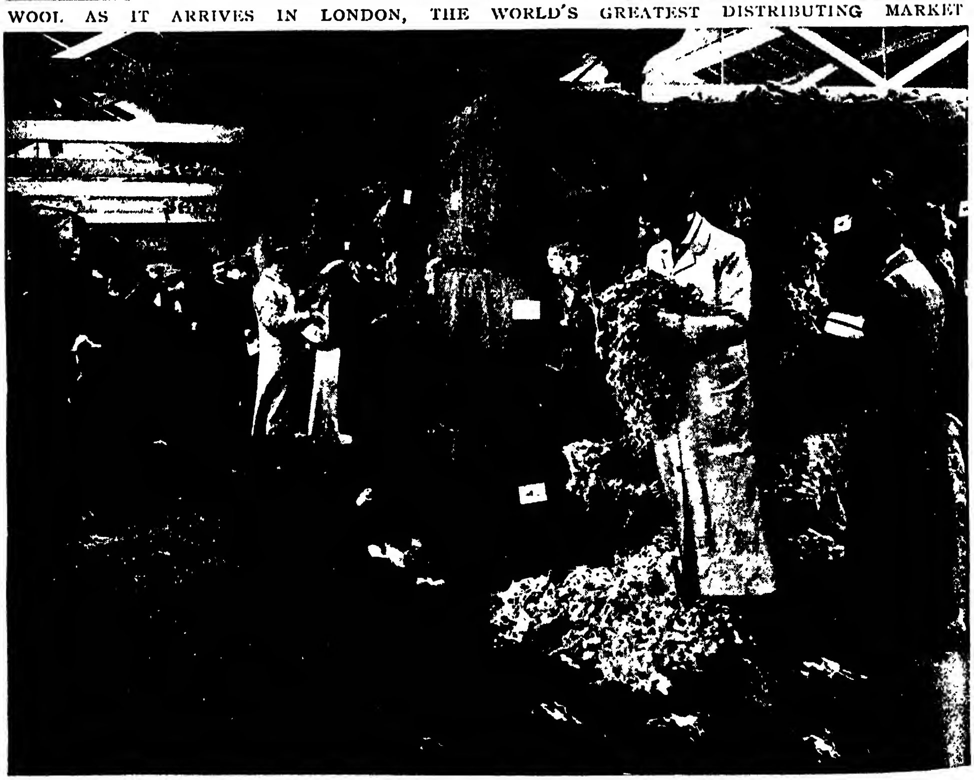
SCENES ON AUSTRALIAN SHEEP FARMS

SHEARING SHEEP BY MACHINERY AT THE BURRAWONG STATION, NEW SOUTH WALES

SORTING AND CLASSING WOOL AT AN AUSTRALIAN SHEARING-SHED

THE MARKETING OF WOOL IN ENGLAND

WOOL AS IT ARRIVES IN LONDON, THE WORLD'S GREATEST DISTRIBUTING MARKET



BUYERS TESTING SAMPLES AT A WOOL SALE AT THE LONDON DOCKS

Alsatian, who, according to Dr. Smiles, received his inspiration while watching his daughters combing out their long hair between their fingers. His patent was taken out in England in 1846, and, as improved by Schlumberger, it became a practical success, but was bought up in this country to make a clear way for the Lister inventions.

The suppression of the hand-combers by machinery was one of the tragedies of invention, from the point of view of the workers. Long and steadily did these poor fellows fight against the inevitable, in the manner pictured in Charlotte Brontë's "Shirley." Now the machine triumphs all along the line, whether in combing, or spinning, or weaving.

The processes by which wool is prepared for the woollen and worsted types of fabrication are partly common to both, and then diverge. The first step common to both is the sorting or stapling of the wool. The fleece of a single sheep contains many different qualities of wool; and the sorter, as he goes over the fleece, shears in hand, clips the different qualities, and throws them into an array of baskets varying from five or six in number to thirteen or fourteen. The wool differs not only according to the breed of the sheep, and the part of the body from which each lock is taken, but also according to the age of the animal. The finest wool is found on each side of the neck, on the shoulders, the ribs, and the back; good wool on the thighs, haunches, and tail; and inferior in other parts. These qualities are given special names, as, for example, *picklock* for the choicest wool; *prime, choice, super, head, downright, seconds, abb, livery,* and *breech.* Good English wool stands high in these classes, but not the highest.

The sorted wool has now to be cleaned. It is in a varying state of dirtiness, and always saturated naturally with a compound called yolk, which exudes from the sheep's skin, and contains potash salts that are a valuable manure. The careful farmer will wash out a good deal of this impurity, and appropriate its value for his own use. One of the great difficulties, particularly in Argentina wools, is the presence in the fleece of numberless vegetable burrs that can neither be removed by the sorter nor in the beating and washing processes which follow. The wool, having been beaten, is washed or scoured through a series of tanks till it emerges clean and white.

The aim in scouring wool is to prevent damage being done to the fibre while securing perfect cleanliness. It is easy to make the wool harsh in this process by either too great heat or too strong soap. The washing is now done almost entirely by

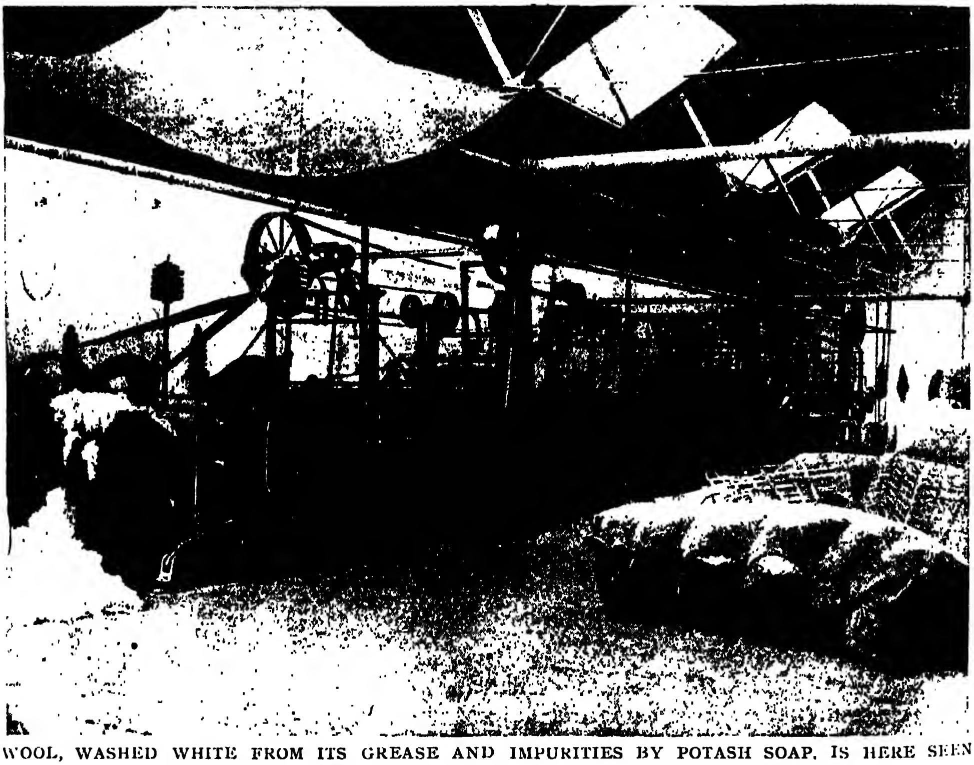
SORTING MOHAIR FOR THE MANUFACTURE OF LIGHT CLOTHS SUCH AS ALPACA

machinery. Wool opens out naturally in water; and the latest tendency is to scour the wool with its own potash salts, through three to five "bowls," the last being for rinsing. It is then passed through squeezing rollers.

After this cleansing process, the wool is dried, slowly and carefully, by various types of machines, which generally utilise a hot-air blast. The dried wool then has to be opened out and loosened, or teased, and this is done in a machine called a *willey*, which separates the fibres through the swift action of a toothed cylinder, revolving against a slower action of "workers," that just clear the teeth and contest for possession of the wool.

A point in the process has now been reached when an attempt is generally made to free the Argentina wool from its burrs. This is effected by one of two methods—either the burrs are removed mechanically by a machine working on much the same principle as the willey, and knocking off the burrs, or by the use of a carbonising agent that will destroy the vegetable burr without injuring the animal matter of the wool. These methods of utilising the Argentina wool have added greatly to the amount of raw material available, as formerly the burr-encumbered South American wool could only be used for quite inferior cloths. Indeed, much of it was exported to the Continent, because it was not regarded as reaching the English standard.

The washing and drying of the wool has removed its natural oiliness and left it difficult to work. It is therefore now oiled, whether it is about to be made into woollen or worsted yarns; and henceforward there are considerable differences in the modes of its treatment, according as it is to be carded and milled or felted as woollen cloth, or to be gilled and combed before being spun into yarn for worsted goods. In either case the operations are so increasingly complex, as the making of cloth becomes more elaborate and mixed, that only the barest outline can be indicated.



WOOL, WASHED WHITE FROM ITS GREASE AND IMPURITIES BY POTASH SOAP, IS HERE SEEN DELIVERED CLEAN BY THE LAST OF THREE SCOURING-TANKS

Take first the production of woollen cloth, although it is more and more difficult to find such a thing in purity. Cloth, by preference, is made from short wools that will form the more readily into a fluffy yarn, which felts or mats naturally, and the object of the process is to cause the fibres to

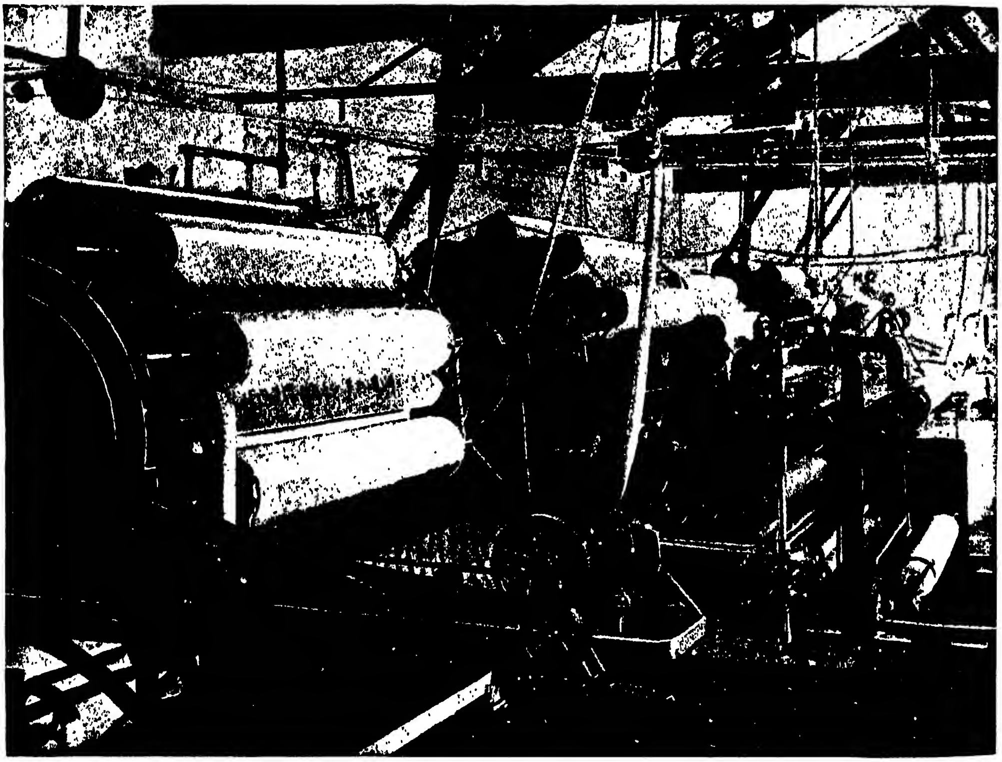
MAKING THE WOOL READY FOR USE

DRYING THE WOOL, TO REMOVE SOME OF THE HARSHNESS CAUSED BY THE SCOURING

THE OPENING OUT AND SEPARATION OF THE LOCKS OF WOOL BY THE WILLEYING MACHIN

be thoroughly interlaced and mixed. But first, with the oiling, comes the blending; and into the blending operation can go not only all kinds of wool, but all kinds of other material: ground-up garments—known as *mungo;* blankets, stockings, rags—known after treatment as shoddy; flocks, wool, waste, cotton, silk-waste, and anything of a similar character. These materials are all passed through the willow or the fearnaught machines, and are torn up. They are then laid in layers one over the other and oiled as each layer is added, till there is a "blend-stack" of different stuffs. This is passed through the willow and fearnaught in combination, further lubricated with olive oil, and then lacerated and mixed in a machine known as the *scribbler*. This terrific tearer has fifty million teeth, with which it separates and intertwines the fibres until the whole has reached a state of mixing absolutely determined by the machine, and in no way dependent upon the lie of the fibres when the varied material entered the machine. The material is now a complete amalgamation, but in no sense a thread, and it is passed to a *condenser* which divides the sheet of made stuff into strips, and rolls them into soft "slivers," that are twisted and spun into yarn by the spinning-mule in the next principal process.

When the yarn has been woven into "raw" cloth it has to undergo many forms of treatment before it becomes saleable as the public knows it; and according to the number and character of these operations, as well as its component materials, it emerges as rough or smooth, loose or close in texture. It must undergo perching to find defects, knotting, scouring, drying, and mending, and then comes the most characteristic of all the processes in woollen manufacture—that of milling or felting. Up to this time the lines of the weaving of the cloth can be clearly traced, but under the felting that follows the cloth becomes an apparently homogeneous mass, without any threaded structure.



THE CARDING-MACHINE STRAIGHTENING AND ARRANGING THE FIBRES OF THE WOOL

It is a special feature of wool-fibre that it will take this solidity of texture. Milling is effected in one of two ways. Either the fabric is pounded with huge hammers in what are called the stocks, after being saturated in a soap solution; or it is compressed between the rollers of a milling-machine till the whole surface becomes

closely matted. This felting is the natural conclusion of the carding which completely mixed and intertwined the component fibres. The piece of cloth is now ready for finishing.

After scouring to get rid of the soapy compound that has caused its fibres to expand and coalesce, it is stretched on a tentering-frame and dried. The surface of the cloth is then *raised* by teazles mounted on a cylinder, the fibre being brushed up. If a velvet finish is required, the fabric is "raised" wet. The surface of the cloth is now made even by cropping, and the final appearance is given to it by steaming and pressing.

have been back-washed, straightened, combed, straightened, drawn, and spun, and regularity of fibre has been attained.

First, the long wool is fed into a series of gill-boxes, the object being to straighten and make parallel the fibres of the wool. While passing through these preparing-boxes the locks of wool become dirtied as they had previously been oiled; they are therefore washed, and, having been passed through more gill-boxes for restraightening, the combing process begins. This is the stage where invention has chiefly been at work in the world of wool, as we have already described. The machine that is now

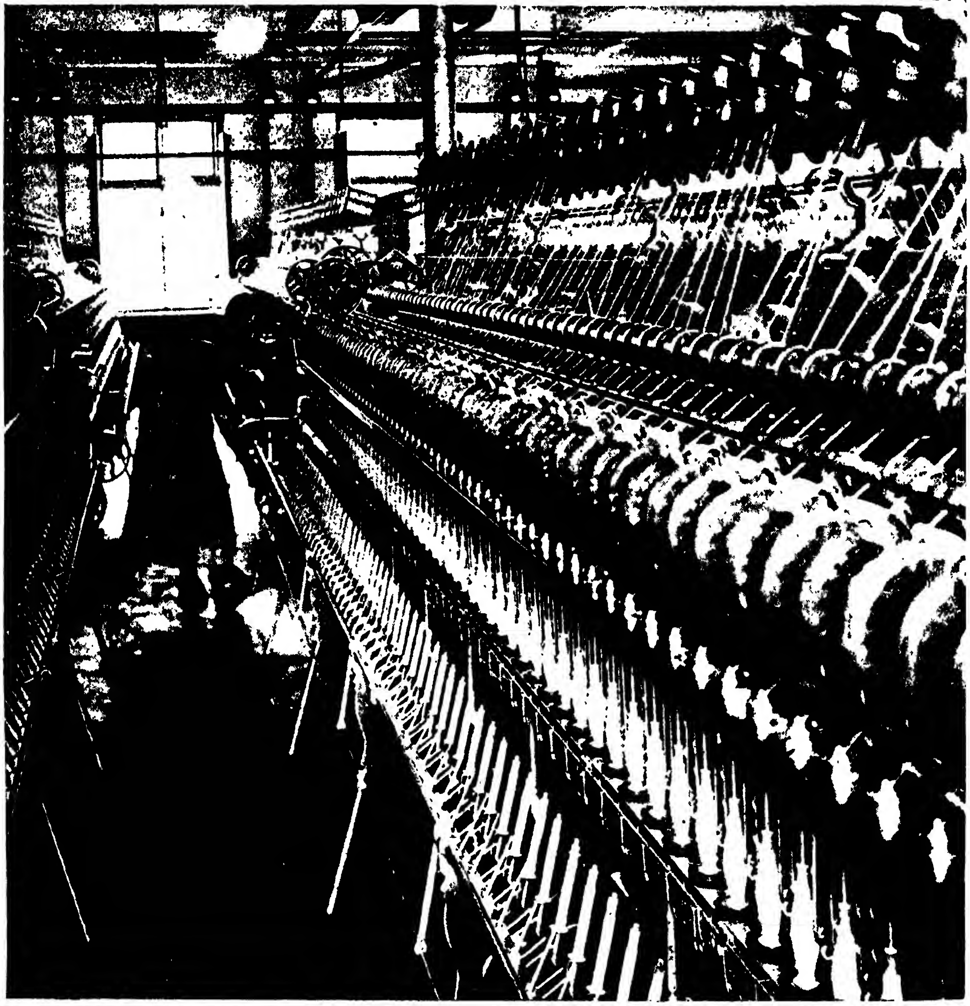
COMBING THE WOOL SO THAT IT COMES OUT OF THE MACHINE WITH FIBRES PARALLEL, AND FORMS A FLEECY "SLIVER"

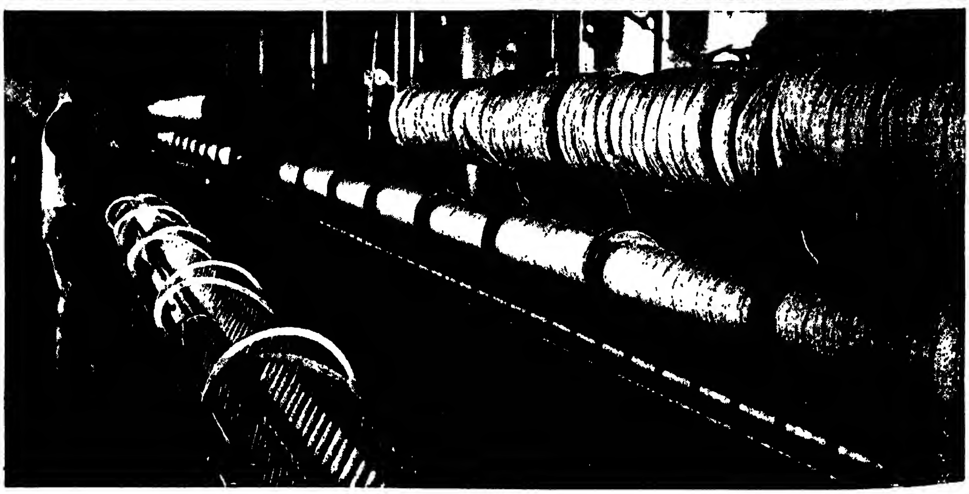
In the case of the worsted fabrics the wools chosen are those with a long and lustrous fibre, such as the British Leicesters and Lincolns; and the chief aim is to keep the fibres straight, instead of intertwining them as in the scribbling stage of the woollen process. Worsted has been defined as long wool combed and spun, and woollens as short wool carded and spun and milled, but in recent years all these distinctions have been disregarded in some materials, so that worsted yarns that have not been combed are known; and worsteds are sometimes milled. The distinctive features, however, of worsted fabrics are that they

in most general use for combing is the Noble. The combing-machine not only straightens the fibres, but it sorts the wool, separating the short-fibred from the long. Later, what are called drawing-machines are used to secure a uniform sliver from which an even thread can be spun.

The spinning of worsted yarn differs considerably from the spinning of woollen thread; the weaving is performed in the usual way, and is a far more essential process with worsted than is the case in the weaving of woollen cloth. The finishing of various fabrics depends almost entirely on their style; and quite small differences in

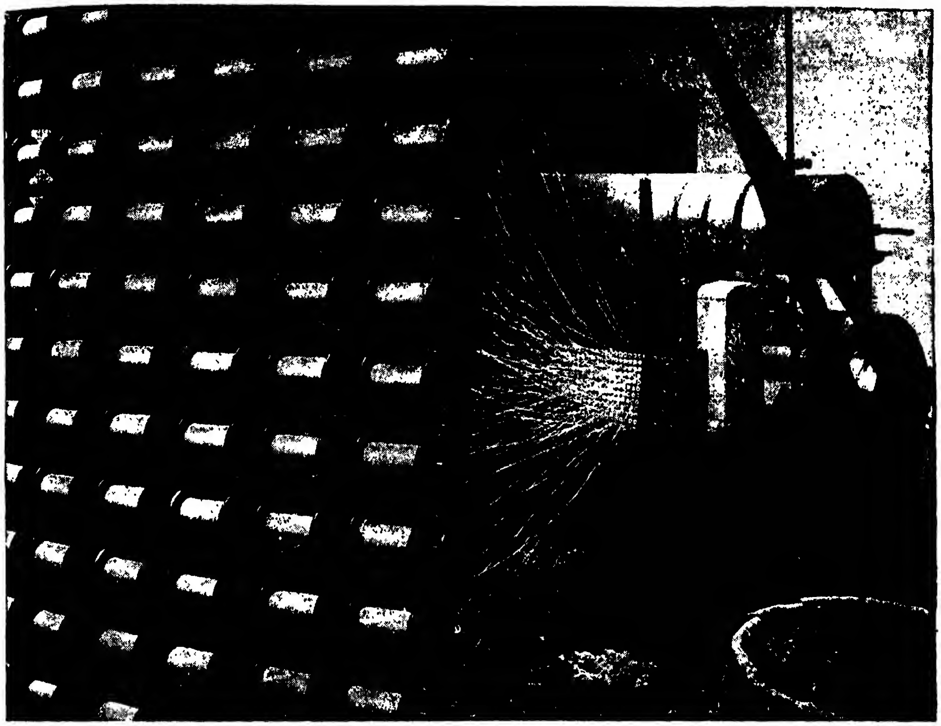
MACHINES THAT SPIN WOOL INTO YARN

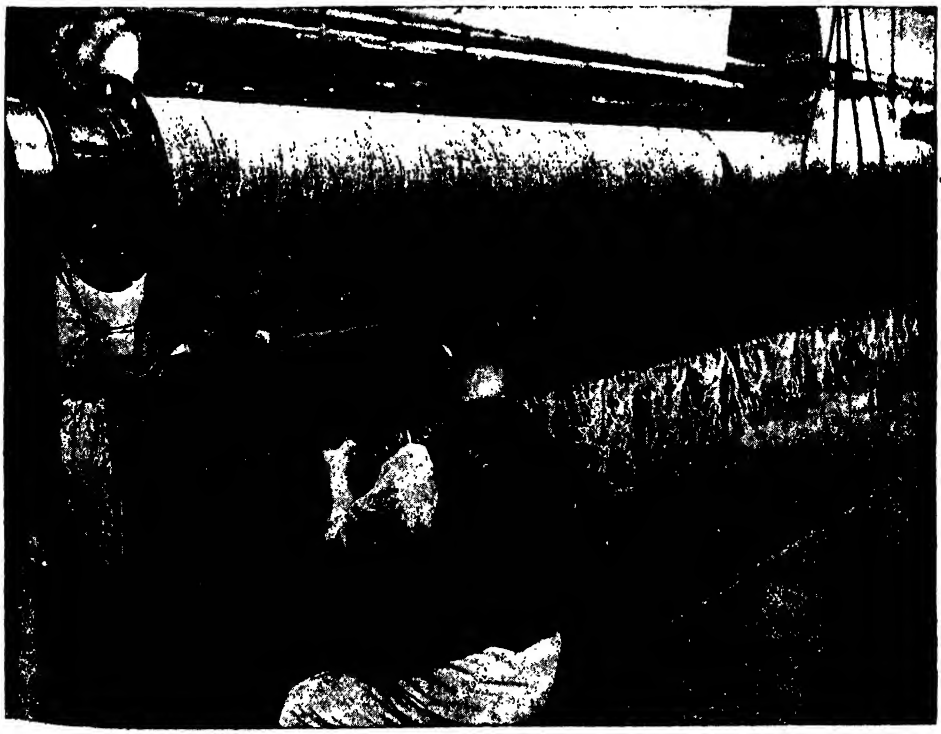




THE UPPER OF THESE MACHINES WILL PRODUCE OVER THREE HUNDRED AND FORTY MILES OF YARN IN A DAY

WARPING, SIZING, AND DRAWING IN





PROCESSES THAT IMMEDIATELY PRECEDE THE WEAVING OF WOOLLEN YARN INTO CLOTH

outward appearance and manufacturing method, as it would seem to an outside observer, divide business from business.

The range of woollen manufactures, apart from all minor differences, is enormously wide in quality and character. It extends from the wide-meshed, rough, scented, animal-reminiscent texture of the Harris tweed to the finest, smooth broadcloth. The tweeds alone make a great class, ranging from pieces that have a fine appearance for a brief period of wear, owing almost entirely to the finishing, to pieces that seem as if they never will wear out. Others, again, are for ever like a crumpled rag after one heavy shower · and the only way of steering safely through the dangers of the clothing trade is to trust to the reputation of a good firm for quality, and go to another firm if you are deceived.

Many of the latest styles of predominently woollen and worsted goods are frankly mixtures with cotton or silk; or they are woollen and worsted together. These mixtures are necessary because of certain faulty tendencies in fabrics of wool, such as the disposition to shrink after being wetted, a tendency particularly noticeable in the woollen underclothing that has now become such a marked and promising feature of modern hygienic dress.

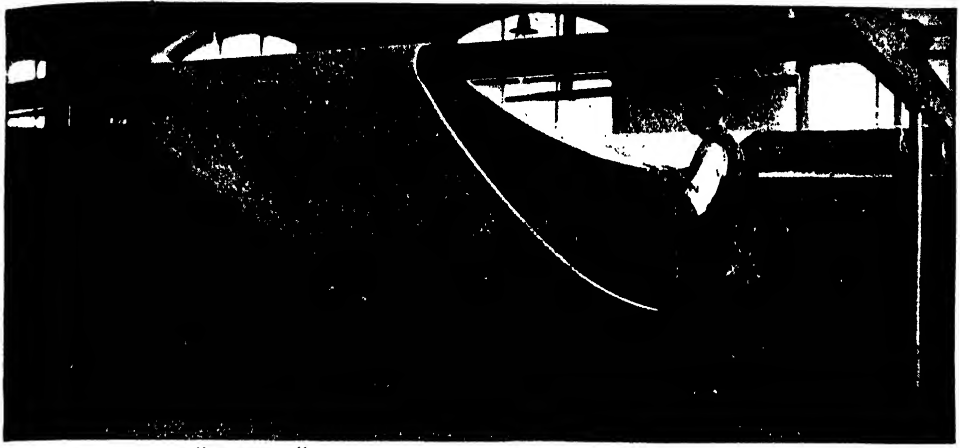
The largest class of woollen cloths is the tweeds, which are being used more and more for ladies' as well as men's wear. Meltons, beavers, doeskins, buckskins, and diagonals are other varieties. The worsted textures cover a still wider range, and can be got up to make a more powerful appeal to the eye, owing to the lustre they will take a lustre that readily passes into tell-tale shininess.

Worsteds are now used largely for all forms of men's suitings, and in delaines, voiles, merinos, cashmeres, crêpe-de-chines, Amazons, Orleans cloth, alpacas, moreens, and the many varieties of bright, smooth fabrics in which Bradford competes not unsuccessfully with the artistic products of the French centres, such as Roubaix.

THE WEAVING-LOOM, WHICH PRODUCES CLOTH IN ITS FIRST CRUDE, UNFINISHED STATE

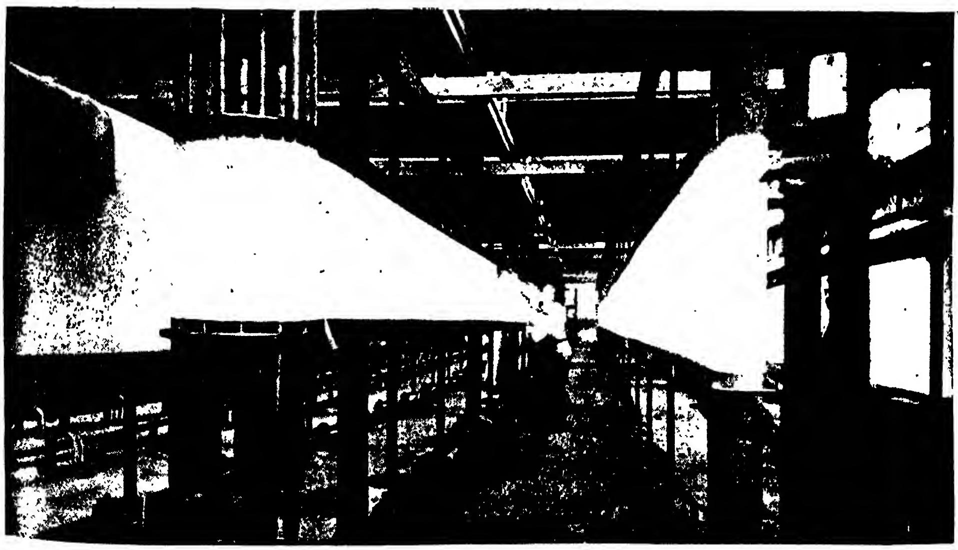
The manufactures from wool have never been geographically concentrated so exclusively as manufactures of cotton, perhaps because the production of the raw material is world-wide, to an extent quite unparalleled in cotton. Though Great Britain leads the trade of the world easily in quality matched with price, each of the great manufacturing nations has a substantial trade in woollen goods. The French excel in finish, and they have a very honourable record for ingenuity in their development of the industry through

FINISHING PROCESSES FOR WOOLLENS



"RAISING" WOOLLEN CLOTH, OR PUTTING ON THE NAP

STRETCHING THE CLOTH BEFORE IT IS DRIED



STRETCHING CLOTH WHILE IT IS IN THE DRYING-ROOM

inventions and improvements in machinery. Alsace has long been a wool-working centre, with Mülhausen as its industrial capital. The wools of Silesia and Saxony have a well-established repute; and the manufacturers of these parts of Germany compete keenly for the trade of the world, particularly in underclothing and hosiery.

The United States by her tariffs has carefully fortified her woollen manufactures against English competition, with the result that she unnecessarily pays more dearly for her clothes, if quality and price are considered, than any nation in the world. But it is admitted on all hands that it is only by the consumers' sacrifices in high prices that she prevents herself from being swamped by the superior woollens and worsteds of Bradford. When all the economic conditions of the American trade in woollen textures are taken into consideration, the industry appears to be one of the most artificial in the world. It pays a wealthy, well-dressed American to make an annual journey to England to fit himself out with new clothes, the cost of the voyage being less than the tariff on the goods he feels constrained to wear.

MILLING, OR SOLIDIFYING CLOTH BY PRESSURE

The manufacture is spread widely over Great Britain, just as it is spread generally throughout the manufacturing world. Even Norwich retains a remnant of its ancient trade. The business that was once centred on Bristol in the West is now diffused through parts of Gloucestershire, where quite the best cloth in the world, of some descriptions—particularly broadcloth—is made. Scotland, noted for its great upland sheep-farms, has given a name to some of the best known cloths—tweeds and cheviots—and, appropriately, the manufacture is located in the Lowlands, at Hawick and Galashiels. Leicester has made a special feature of underclothing, and in recent years has recovered much of the trade which was going to German specialisation; while Nottingham and South Derbyshire keep a large hosiery trade, inherited from the days when "stockingers" were the industrial workers of a numerous group of villages in Nottinghamshire, Derbyshire, and Leicestershire.

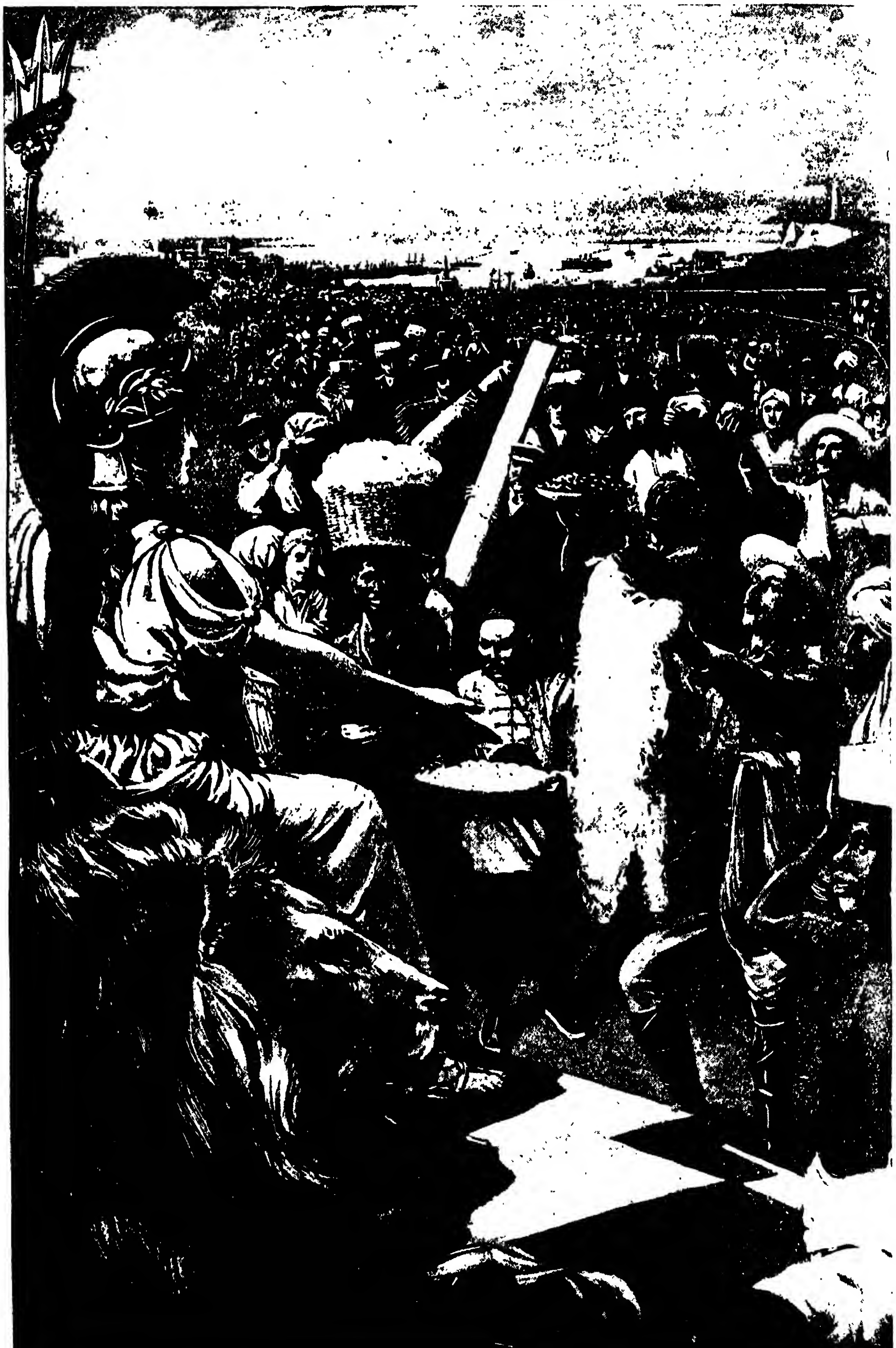
But it is the West Riding of Yorkshire that leads the way in woollens, and particularly Bradford challenges comparison with all the world for its modern highly finished fabrics. It seems as if the specialised trades were drawing in towards the West Yorkshire centre. Thus, though mid-Wales retains its blanket trade to some extent, and even rural Witney is not entirely superseded, that trade has collected largely in modern times around Dewsbury and Batley, Dewsbury being particularly the centre for the shoddy business, or, as it is more respectfully named, "re-manufactured" woollens. Kidderminster still keeps its carpet industry, but Halifax is the chief business centre in that department. It may be said confidently that while special "lines" in the wool industry are sustained successfully in the rural districts through which they have been scattered for many generations since the Flemings and Walloons first established them throughout England wherever a good wool supply was readily available, every separate form of the industry finds a modern home in the West Riding; and Bradford is as truly, though not as exclusively, the centre of the woollen world as Manchester is of cotton.

Comparisons are sometimes made between the relative growths of the cotton and woollen industries, and it is claimed, with truth, that cotton proportionately takes the lead. This must be so, for while all the world wears cotton, all the world will never wear wool; and scope for the extension of clothing among the comparatively unclothed is to be found chiefly in the

tropical regions, where cotton is the natural wear. Cotton, too, is invading the domain of wool as a co-operating material that prevents shrinkage. Still, wool, as the provider of the most sanitary material, and the best preventive of chills where temperatures are low or varied, must serve an increasing multitude throughout the temperate zones; and there is no lack in design and execution to make it a keen competitor in fashion with the materials of finer texture.

Though the wool industry is world-wide in its operations, from first to last, in a predominant degree its modern development is due to the energy of the British race, for it is the British colonies—Australia and New Zealand—with the Argentine, largely developed by British capital, that produce the great bulk of the wool whereon the manufacturers of all the leading industrial nations rely. We may let our thoughts range over the world while we recall the scenes, touched with romance, from whence the materials of the trade come—to the alpacas of the Andes and their wool supplies destined for the mills of Saltaire; to the remote inland regions of Asia Minor, where the Angora goat produces mohair; to the mountains and lower grazing grounds of Spain, where, by immemorial custom, the great flocks of Merino sheep make their seasonal migrations, till in them the demand for change from valley to height has become as imperative as the October call from afar to the English swallow. Then we may bring our thoughts back to the fat lands of Lincolnshire, with their big-built sheep, and the green pastures of Leicestershire, that supply a large part of the world with flannel; or we may think of the breeds of moorland sheep—strange to the sight in some instances, as, for example, the lonk—or the Cumberland flocks held as part of a tenancy with the stony land on which they feed, and always kept up to a prescribed number, or the sheep of the Cheviots and the Lowland dales, associated with the shepherd poesy of Scotland; but these and all other varieties would not have sufficed for the wants of the world had there been no development in the pastoral lands of Australia, New Zealand, and the Argentine. Australia, in particular, is the continent of the sheep. It is only by the specialised pastoral work of the British colonies and its output in wool that the manufacturing activity of Great Britain has been made possible.


DRYING AND FOLDING THE COMPLETED PIECE



AN ARTIST'S CONCEPTION OF THE CALL OF GREAT BRITAIN ON THE PRODUCE OF THE WORLD

OUR WORKSHOP SUPPLIES

Great Britain's Extensive and Increasing Dependence Upon Her Imported Materials

THE IMPORTANCE OF INSULAR SECURITY

In earlier chapters we reviewed broadly the commercial position of the United Kingdom, and saw that British work is in large part necessarily done upon imported materials. The feeding of British factories is as vitally important to the national welfare as the feeding of the bodies of the British people, which we have just considered. Indeed, it may truly be said that the security of our supplies of materials ought to come first in our consideration, because if we had not materials to work upon it would be impossible for our people to earn the means of buying food.

When supplies have been securely and regularly received for a long period of time, we are prone to regard them as commonplace, and scarcely deserving of prolonged consideration. In that lies one of the economic and national dangers of the British people. The fact that materials are always at hand when needed, in apparently unlimited supply, is only too likely to blind us to the fact that they are secured by commercial operations of enormous complexity and magnitude, and secured to an island people by the command of the sea. To the British people the necessity for imports to maintain nationhood—the extraordinary fact that without them the population of the British islands would be very small—constitutes a veritable heel of Achilles. It is the vulnerable point in our national economy. Let us see what is the extent of this dependence upon commerce to which we have referred.

There are a certain number of manufacturing industries which are, for practical purposes, independent of foreign supplies. Amongst these may be mentioned the manufacture of bricks, of cement, of china, and of earthenware. The materials for these we have native and in abundance, and we have, of course, native coal with which to work them. Apart from these, however, it is difficult to name any manufacturing industries of importance which are able to dispense with foreign material. Even the iron manufacture is not independent of foreign ores. In 1910 there were raised in United Kingdom iron-mines over fifteen million tons of iron ore, but their value was little more than £4,000,000, whereas we imported just over seven million tons of iron ore, which were worth over £6,000,000. That is to say, we have to import a larger quantity of rich iron ore to use with our own poorer material.

Our agriculture, as well as our manufacturing industry, it may be remarked in passing, is in no small measure dependent on foreign raw material. We consume a considerable quantity of imported manures. If we increased our home production of foods, we should enlarge our call for foreign manure. This is a point which is often overlooked in discussions of the food problem.

When we glance down the Home Office account of our native mineral production, we see that the only items which stand out in really large quantity are coal, clay, chalk and other limestone, gravel and sand, iron ore, salt, sandstone, and slate. Of important metals like lead, copper, and zinc, our supply is not large enough to sustain industries of any magnitude. As for the textile industries, they are almost entirely run on imported material. As to building and wood-working trades, our houses and our furniture alike have to be constructed of timber imported from abroad. Similarly, with regard to animal, vegetable, and mineral oils, we have to rely almost entirely on foreign supplies. And this is to say nothing of the purely exotic materials, such as rubber, gutta-percha, etc. It follows that an exceedingly good test of the progress of British manufacturing industry can be made by analysing our imports, and finding what part of them

is made up of raw materials. In recent years this has been done by the Board of Trade. Figures are available for the last 13 years.

UNITED KINGDOM IMPORTS OF RAW MATERIALS FROM 1899 TO 1911

Year	A Total Imports	B Of which Re-exported	C Net Imports for Home Consumption
	£	£	£
1899 ..	150,500,000	34,600,000	115,900,000
1900 ..	172,000,000	32,800,000	139,200,000
1901 ..	167,100,000	36,700,000	130,400,000
1902 ..	168,900,000	37,700,000	131,200,000
1903 ..	173,300,000	39,900,000	133,400,000
1904 ..	181,900,000	38,800,000	143,100,000
1905 ..	187,900,000	43,400,000	144,500,000
1906 ..	211,100,000	46,900,000	164,200,000
1907 ..	241,200,000	52,600,000	188,600,000
1908 ..	203,400,000	45,300,000	158,100,000
1909 ..	220,100,000	54,400,000	165,700,000
1910 ..	261,200,000	63,300,000	197,900,000
1911 ..	242,200,000	59,900,000	182,300,000

In the first column of this table is shown the total importation of raw materials. The second column shows the part re-exported in the merchant trade, and the third column, by subtraction of column B from column A, the net imports of raw materials into the United Kingdom for the consumption of British factories and workshops. It will be seen that the net imports for consumption have risen in the thirteen years from £115,900,000 to £182,300,000, an increase of £66,400,000, or 57 per cent. It should be observed, however, that there has been a certain rise in prices in this period, to which we shall have occasion presently to refer in more detail, but when this is taken into account the increase is certainly not unsatisfactory.

A moment's consideration will show that, as our population increases, our dependence upon these imported materials must also increase. Our native supplies, unfortunately, so far from increasing as our population increases, diminish with the depletion of our mines. *Year by year, therefore, the British population, as a whole, has to look for a larger proportion of the basis of its work to countries oversea.*

It is impossible to exaggerate the importance of this point. We have now over 45,000,000 people; and although, as has been pointed out in a previous chapter, the rate of increase has fallen greatly through the combination of a drop in the birth-rate and an increase in emigration, every increase that is recorded, however small, helps to accentuate the peculiarity of our insular position.

It is not the case with imported materials (as we saw it to be the case in the last chapter with regard to imported food) that we are deriving an increasing proportion from within the British Empire. The facts on this head are examined in the following brief statement, which can only be taken down as far as 1910, the latest year for which an analysis is available.

FOREIGN AND IMPERIAL SOURCES OF RAW MATERIALS

Year	Foreign	Imperial	Total
	£	£	£
1899 ..	100,900,000	49,600,000	150,500,000
1900 ..	120,900,000	51,100,000	172,000,000
1905 ..	135,800,000	52,100,000	187,900,000
1910 ..	181,100,000	80,100,000	261,200,000
Increase	80,200,000	30,500,000	110,700,000
Increase	79%	62%	73%

We see that our imported materials, in the period examined, have been drawn in an increasing proportion from foreign sources. Nevertheless, the very considerable actual increase in the purchases of raw material from within the Empire by the United Kingdom should serve, as in the cognate case of food, to suggest to the various British dominions that it is as much to their interest as that of the United Kingdom to maintain the inviolability of the sea connections of the Empire.

It should further be observed that the figures which have been quoted above do not cover all raw materials which are imported for the purposes of British trade. It will be understood that we import from oversea a large quantity of crudely manufactured stuff, such as bars of copper, ingot of lead, etc., which, although not classified as "raw materials" by the Board of Trade, are just as truly raw materials and just as vitally necessary to our economy as the things such as cotton, wool, timber, etc., included in the tables which have been given. We see that a very large section indeed of our population would be reduced to idleness and starvation if we could not command every year, by means of commerce, some hundreds of millions of pounds' worth of various raw and crude productions.

It is impossible in this treatise to show in detail the whole gamut of our material supplies. We give on page 2559, however, an account of the sources of the leading

materials, distinguishing foreign and Imperial supplies, and showing, for each commodity treated, the main countries upon which we are dependent.

In but few cases do we derive an important material in chief supply from the British possessions. These are tin, of which the best supplies in the world are found in the Straits Settlements; jute, which is almost entirely derived from British India; and wool, by far the greater part of which comes from Australasia.

The Welfare of Great Britain Hanging as by a Thread on Foreign Supplies

For some materials of indispensable character we have almost entirely to depend upon foreign countries. Notable amongst these are cotton, of which the United States has at present almost the monopoly; iron ore, which we chiefly obtain from Spain; copper, which comes mainly from the United States; zinc, the chief source of which is Germany; mineral oils, the best suppliers of which are the United States and Russia; silk, the best markets for which are China and Italy; and timber, which is mainly derived from the North of Europe.

Bringing the world to market in the United Kingdom is thus seen to be one of the first of British interests. Upon it the welfare of the United Kingdom, as a community, hangs as by a thread. We have built about us, in palace and in cottage, in town and in country, the woods and metals of every country under the sun. Not only the food we eat, but the garments we wear, the furnishings of comfort which surround us, the tools, implements, and machines of agricultural and manufacturing industry, are composed in great part of the foreign and Colonial commodities which we have examined.

The Raiding of British Resources by the Growth of New Countries

In view of the peculiar importance of the British raw material supplies, let us consider the great causes which have influenced them and their prices in recent years, and the prospects as to the future. The major factors are of deep and general importance.

During the greater part of this period—say, 1870–1900—the progress of the world was marked by what may almost be termed the raiding of its natural resources. What we still call "new" countries gained enormously in population, and what they possessed of natural wealth in fields, in forests, and in mines was rapidly exploited.

Take, for example, the greatest of the "new" countries, the United States of America, and observe its progress as measured by its population.

GROWTH OF POPULATION IN U.S.A.

1870	38,500,000
1875	44,000,000
1880	50,000,000
1885	56,000,000
1890	63,000,000
1895	69,000,000
1900	71,000,000
1905	84,000,000
1910	92,000,000
1911	94,000,000

Here is a picture of growth which can only be described as bewildering in its rapidity. This growth occurred in a country of enormous area—over three million square miles (observe that the United States has still only about thirty people to the square mile), and of unparalleled natural resources. Indeed, it was, of course, the presence of these extraordinary resources which attracted the immigrants. Thus, to deal with this particular part of the world alone, there were added to the world's supplies of materials the first rapid exploitation by modern methods of gigantic supplies of minerals and timber, and virgin fertility. The United States literally poured out upon the world what was for many years an apparently limitless stream of corn and oil, meat and dairy produce, timber and metals.

Our Supplies Stopped by American Home Consumption of Raw Material

These American supplies came to be looked upon as commonplaces of commerce—things to be depended upon for an indefinite period. A moment's thought will show, however, that the virgin resources of the United States were limited and definite within very narrow confines. The exportation of easily garnered wealth could only proceed for a space of years counting for little or nothing in history. Then it became clear that America was not to be depended upon. We saw in the last chapter how, as recently as the years 1898–1902, we could look to the United States of America every year for the supply of about sixty million cwt. of wheat, but that in 1905 the supply had dropped to fourteen million cwt., and was in 1910 only eighteen million cwt. We saw also that a similar change has taken place with regard to the American supplies of meat, two things working together to one end: (1) the area of virgin soil contracting, and (2) the population, and therefore the home demand for American produce, increasing with amazing rapidity. It will be obvious that what is true of American corn and

American meat is also true, in varying degree, of American cheese, American timber, and American metals.

Further, the processes through which the native resources of the United States have passed are processes which have been, or will be, repeated in every "new" country in the world. Some countries simultaneously with the United States, and others a move behind the United States, have been or are bringing to market with great speed those supplies which are most easily worked, soils of such richness that for many years they can be cropped without manuring, forests of wide expansion, mines whose first opening out yields ore of good quality at a low price.

The last forty years have witnessed a cycle of such changes. During the greater part of the period the opening up of the world's resources proceeded at a rate more than ample to meet demand, and there was consequently a great fall in prices, a fall which was aided by the great fall in sea-freights to which we referred when considering coal in Chapter 17. At the end of the nineteenth century, however, a point was reached at which the opening up of "new" lands could no longer proceed rapidly enough to meet the greatly increased demands of modern civilisation; shortage in relation to demand began to be experienced in connection with a large number of commodities, and prices rose. The rise was aided by the new methods of gold-mining, which added enormously to the stock of gold of the world, and therefore affected prices now almost universally measured in terms of gold.

The course of prices in coal and the chief metals is shown in the table below.

PRICES OF COAL AND METALS

Year	Coal	Pig Iron	Copper Ore and Regulas	Crude Zinc	Block Tin	Lead
1871..	58	72	89	99	96	126
1872..	94	120	103	98	105	128
1873..	124	148	102	113	102	144
1874..	103	112	95	107	75	134
1875..	79	86	99	109	66	133
1880..	53	76	91	91	68	98
1885..	53	51	62	68	65	66
1890..	75	73	71	110	72	78
1895..	56	57	61	72	48	60
1900..	100	100	100	100	100	100
1905..	63	75	88	112	108	78
1906..	65	83	112	123	136	99
1907..	76	88	124	115	132	113
1908..	76	75	89	98	101	80
1909..	68	77	84	106	102	77
1910..	70	81	82	111	17	76

The facts of the table are expressed by the convenient and illuminating method of index-numbers; the prices of the year 1900 are represented by the figure 100, and the prices of other years expressed as percentages of those of 1900. Taking coal, for example, and representing the price of coal in 1900 by 100, we see that in 1871 the price of coal was 58 per cent. of the price of 1900, while in 1910 it was 70 per cent. of the price of the year selected as a standard of comparison.

The table opens with the group of years which were so seriously affected by the consequences of the Franco-German War. In 1873 prices for nearly all commodities touched a level which has never since been exceeded. By 1875 prices were righting themselves, and then began the great fall in prices which continued during the succeeding twenty years. With 1895 the fall ended, and an upward movement began, which has since continued more or less uninterruptedly for many articles, but not for all.

PRICES OF TEXTILE MATERIALS
(The facts relate in each case to *raw* materials)

Year	Cotton	Wool Imported	Wool British	Jute	Flax	Silk
1871	135	138	222	147	121	167
1872	163	151	264	133	135	165
1873	154	153	282	106	129	102
1874	139	153	262	113	126	120
1875	133	161	281	102	137	118
1880	113	144	221	118	119	131
1885	110	106	127	77	107	108
1890	102	108	132	91	87	110
1895	74	85	127	75	88	97
1900	100	100	100	100	100	100
1905	101	98	158	116	111	101
1906	119	108	167	153	118	100
1907	127	109	185	152	107	118
1908	116	99	125	113	100	93
1909	118	101	141	103	111	89
1910	156	107	167	107	118	91

The general character of the rise in the price of materials since 1895 will be plain if the table relating to metals is compared with that relating to textile materials on this page, and that relating to miscellaneous materials on page 2557. Out of seventeen important materials included in these records, as many as thirteen have risen in price, many of them considerably, in the last fifteen years. The exceptions to the rule of increase of price are of much interest. Take

silk, for example. The supply of raw silk depends not upon the exploitation of natural resources, but upon the artificial breeding of silkworms. It is not surprising, therefore, to find that this particular raw material has fallen in price rather than increased.

Timber, on the whole, it will be observed, has remained stationary in the last fifteen years, and the price in 1910 was rather less than in 1895. The explanation of this is that the conservation of timber in Europe has for many years been a subject of State solicitude. Germany, for example, has not allowed her timber to be wasted without renewal, as the United States has foolishly done. We owe it to wise conservation of natural resources that timber has not obeyed the general rule of rapid increase of

PRICES OF MISCELLANEOUS MATERIALS

Year	Timber (Hewn Fir)	Bricks	Rubber	Hides	Petroleum
1871	159	92	77	121	314
1872	163	100	82	138	311
1873	177	117	81	143	273
1874	180	100	75	147	212
1875	157	92	75	141	183
1880	134	75	103	126	155
1885	116	75	81	127	142
1890	106	100	91	98	105
1895	88	83	81	90	87
1900	100	100	100	100	100
1905	88	81	119	113	83
1906	90	78	103	123	90
1907	92	79	119	132	92
1908	88	81	107	119	89
1909	84	75	148	127	75
1910	84	75	219	135	75

price of the last fifteen years. Another example is the price of bricks, which it will be seen was lower in 1910 than in 1895. This is a consequence of the fact that the raw materials of which bricks are made, clay and coal, are found in the United Kingdom in ample supply—far more ample than can be trenched upon in many years by the rate of British production, and, further, the price of coal, although greater in 1910 than in 1895, has been balanced by cheaper methods of brick production.

The fourth case is that of petroleum. The supplies of petroleum in the world, although obviously limited, have not yet been trenched upon largely enough seriously to alter the relation of demand and supply. With the increased use of oil, however, this will cease to be the case before many years are over; and nothing is more certain than eventual appreciation in its price.

Many of the other materials in the three tables of prices present figures of exceeding interest. Tin, it will be observed, was in 1910 more than twice the price of 1895. More remarkable still, the price of tin more than doubled in the five years 1895-1900. Cotton, it will be seen, doubled in price in 1895-1910, and wool rose considerably. The causes of these increases have been generally described above, and were discussed in detail in previous chapters. Jute and flax have also risen very greatly in the last half-generation.

It may be observed in relation to all articles of organic origin that there is every hope of eventual lower prices. In all probability, science will aid the agriculturalist and pastoralist to produce both plants and animals on a larger scale than ever before, and a new relation of supply to demand will thereby be achieved. This observation applies generally to cotton, wool, jute, flax, silk, timber, rubber, and hides, all of which are things the supplies of which will in later years be increased indefinitely, after a period during which they may advance to higher prices than those of 1912.

The figures for rubber are some of the most remarkable in the tables. Between 1895 and 1910 the rubber index-number, taking the price of 1900 as 100, rose from 81 to 219, or by 170 per cent. This is a case which specially illustrates the general tendency of world exploitation in modern times. The rubber-trees of the world were very limited in number, and the uses of rubber have increased enormously in the last twenty years. Reckless exploitation took place; and in the short period referred to the world's rubber areas were so rapidly raided that the increasing demand could not long be met. A great deal of replanting has taken place in recent years, and eventually prices will again fall.

With regard to the minerals and metals, the considerations are somewhat different. We cannot at present breed inorganic substances. The remarkable properties of radium have led some investigators to the conclusion that the dreams of the alchemists of old may some day be realised, but it is probably a far cry to the time when chemistry will put transmutation of the elements on a practical basis. It is clear that at the rate at which the world is using up such indispensable metals as iron, copper, tin, lead, zinc, mercury, and aluminium, the best and cheapest supplies of these things will give out long before the twentieth century has grown old. This may or may not

mean scarcity or dearness. Over and over again in the history of industrial science, it has been shown that in very truth necessity is the mother of invention. When man is driven back upon second or third rate ores with only a small metallic content, he will probably learn by improved methods to make them as valuable as, or even more valuable than, the richer and more easily won supplies which at one time the world furnished. Thus we today utilise phosphoric iron ores which at one time had to be rejected in the iron and steel industry. One of the most valuable of metals, aluminium, exists in the world in almost unlimited supplies. Common clay, of course, is a silicate of aluminium; and the time may arrive when the industrial chemist will be able to make aluminium available for an exceedingly large number of purposes.

The case of tin, one of the most useful of the industrial metals, illustrates the general problem of dearness which has arisen in connection with the mineral resources of the world. Here is a record of the price of tin since 1873.

AVERAGE PRICE PER TON OF METALLIC TIN IN THE LONDON MARKET.

Year	English Block Tin	Australian Tin
	£ s. d	£ s. d.
1873	133 7 0	—
1874	108 8 0	92 13 0
1875	90 2 0	83 2 0
1880	91 5 0	86 15 0
1885	89 7 2	86 16 3
1890	97 13 3	94 7 6
1895	67 4 1	64 7 2
1900	137 14 7	133 19 2
1905	143 12 3	142 13 0
1906	181 4 0	181 1 1
1907	174 12 2	173 3 6
1908	133 17 1	131 4 5
1909	133 15 8	135 5 2
1910	153 16 10	153 16 9

This record brings us down to 1910. In 1912 tin is at about £200 a ton, or, say, 1s. 9d. per lb. !

In the 'seventies of the nineteenth century prices were inflated by the consequences of the last great European war. After that tin fell rapidly, until, in 1895, it actually touched £67 a ton. The price is now three times that figure. The rich mines of the Malay Peninsula have been creamed of their richest ores. From this time, tin will certainly advance to an even higher figure, and will come to be counted amongst the precious metals.

Aluminium has actually become cheaper than tin, being now (1912) priced at about £70 a ton. But for this fact it is probable that tin would have advanced even further, for aluminium is in some respects a fair substitute for tin. As tin advances, the inventor casts about for a substitute. Thus it is always with industrial materials. While there is plenty, the natural supplies of the world are no more regarded and no more considered than pebbles on a beach. Necessity is ever the mother of invention, as we saw in the case of coal-mines and the steam-engine.

It is an obvious deduction from our study of British raw material supplies that the commerce of the future must seek to be well informed, and inspired by a scientific regard for the proper adjustment of the needs of man to the wealth of the world. It is clear that the haphazard methods of the past must give way to an ordered consideration of the world as a great estate which needs to be husbanded and conserved. We must not expect to be able to treat the world as a place in which we can reap without sowing. On page 231, Chapter 2, we saw how the population of Christendom alone rose from 240,000,000 in 1831 to 527,000,000 in 1909. Population increases, but the little world to which we are confined does not expand with population. So, as things are at present ordered, some of the resources of the world diminish day by day, even while the population of the world rapidly increases. In earlier ages, before the advance of science, population was stemmed by recurrent famine and pestilence. The modern man, refusing to bow to want or to disease, will increasingly find it necessary to survey the world's resources as a whole, to form a just and accurate picture of the relation of supply to demand in every part of it, and to turn to good account and to enlarge every resource which Nature has provided.

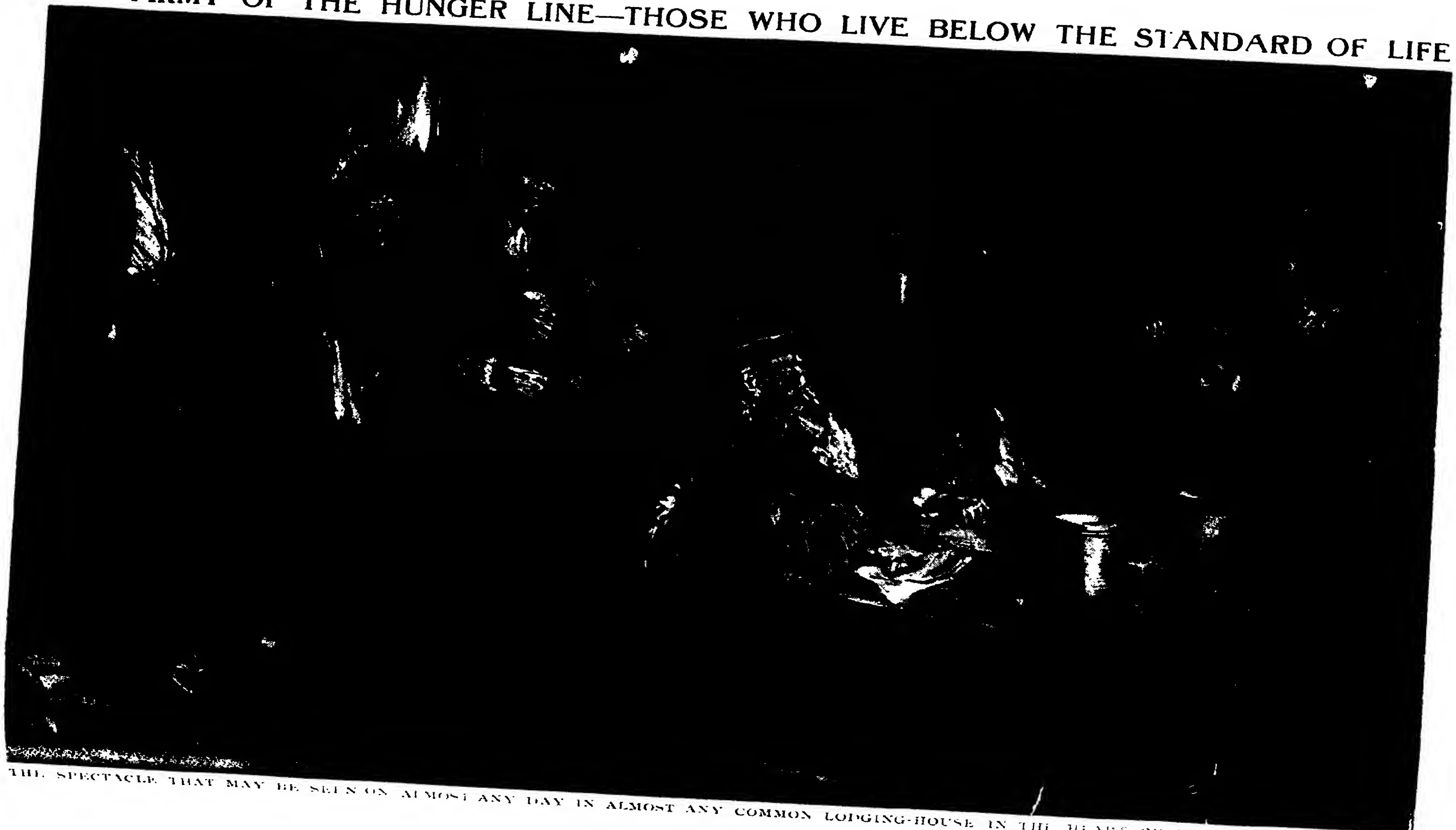
The possibilities which lie before mankind in the directions we have indicated are of infinite grandeur. They can only be realised by those who understand the degree of control of Nature which man already possesses. Even if the powers already at hand were fully exercised in the world, the supplies at the disposal of commerce would be tremendously enlarged. When, in the time to come, an advanced scientific method is fully exercised, the operations of commerce will assume a nobility of proportion which will undoubtedly serve to abolish material poverty.

WHERE OUR CHIEF RAW MATERIALS COME FROM

The sources of our main supplies, according to the latest figures available in 1912

Materials and Chief Sources	Foreign Supplies in 1910	Imperial Supplies in 1910
	£	£
Asbestos: Russia, Germany, Cape of Good Hope, Canada	57,600	56,200
Bristles: Russia, Germany, France, China, India, Hong-Kong	697,600	56,700
Canes and Sticks: Germany, Japan, Straits Settlements, China	66,000	27,000
Caoutchouc: Africa, South America, Straits Settlements, Malay Peninsula, Ceylon	19,579,000	6,517,000
Cork: Portugal, France, Spain	1,029,000	2,000
Cotton: United States, Egypt, India	68,575,000	3,137,000
Flax: Russia, Belgium	3,180,000	6,000
Galls: China, Turkey-in-Asia	35,000	2,000
Gums: Egypt, New Zealand, Persia, Belgium	597,000	1,403,000
Gutta-Percha: Dutch and British Guiana, Venezuela, Straits Settlements	543,000	594,000
Hair (of all kinds): China, Russia, France, U.S.A. ..	732,000	112,000
Hemp: Russia, Italy, Philippines, New Zealand	2,305,000	727,000
Hides and Skins: Russia, Germany, Argentina, Italy, India, British South Africa, Australia	6,315,000	6,568,000
Horns: British India, France, Australia	82,000	86,000
Ivory: Portuguese East Africa, Congo, German West Africa	402,000	124,000
Jute: British India	11,700	4,658,000
Metals:		
Iron Ore: Spain, Sweden	6,197,000	64,000
Copper (Ore or Unwrought): United States, Mexico, Chile, Peru, Spain, British S. Africa, Australia, Canada	6,540,000	1,915,000
Lead: (Ore or Pig): United States, Spain, Australia, Mexico	2,025,000	948,000
Manganese: Russia, Brazil, India	512,000	445,000
Mercury: Spain	401,000	—
Miscellaneous Ores: France, French Pacific, Russia ..	470,000	107,000
Pyrites: Spain, Norway	1,214,000	60,000
Tin (Ore or Block): Bolivia, Straits Settlements, Australia	1,648,000	7,332,000
Unenumerated Metals (unwrought): Germany, U.S.A., France	828,000	67,000
Zinc (Ore or Crude): Germany, Italy, Australia.. ..	3,217,000	134,000
Mica, Talc, etc.: British India, Canada	13,000	104,000
Paper Materials: Algeria, Spain, Russia, Sweden, Norway, Germany	4,768,000	205,000
Piassava Fibres, etc.: British India, Ceylon, Liberia ..	121,000	126,000
Plumbago: Ceylon, British India, Germany	73,000	149,000
Oils, Oilseeds: United States, Russia, Argentina, Egypt, China, India	21,823,000	15,726,000
Shells: Australia, French Pacific Possessions	181,000	406,000
Silk: China, Italy, France	1,474,000	216,000
Skins and Furs: British India, Morocco, Cape of Good Hope, New Zealand, Australia, Belgium	5,187,000	5,046,000
Stone, Slate, and Marble: Norway, Belgium, Channel Islands, Italy	1,030,000	307,000
Timber: Norway, Sweden, Germany, Russia, United States, Canada, India	21,303,000	4,904,000
Wool: Argentina, Australia, France, New Zealand, British South Africa	8,090,000	29,242,000

THE ARMY OF THE HUNGER LINE—THOSE WHO LIVE BELOW THE STANDARD OF LIFE



THE SPECTACLE THAT MAY BE SEEN ON ALMOST ANY DAY IN ALMOST ANY COMMON LODGING-HOUSE IN THE HEART OF A [illegible]

THE PROBLEM OF POVERTY

The Changing Destinies of Rich and Poor, and the Decay of a Vital Part of the Nation

A NATIONAL EVIL THAT MUST BE ARRESTED

It is now pretty generally admitted that the industrial organisation of the civilised world will have to be improved. A very large number of working people in the principal countries are unable to reach the standard of life necessary for themselves and for the race generally. The creation and the development of new industrial forces have profoundly disturbed the position of various classes of labour; and, in some important cases, a once powerful and wealthy order of landowners has also suffered seriously through economic changes. Of course, the decline in the rent value of agricultural land in our own country is not, from one point of view, a national tragedy. It will merely end in the displacement of the descendants of a former aristocratic stock by a plutocracy of new origin. This is an event which has occurred more than once in our history, and it has never ultimately produced any disastrous alteration in the structure of our society. Many a descendant of the conquering Norman is now working as a simple labourer on the domain of his ancestors; and very likely the numerous scions of our merchant nobility of the fifteenth and sixteenth centuries have also fallen back into the working class. These vicissitudes are, generally speaking, a symptom of national strength rather than of national weakness. They indicate a secular circulation of power, talent, and intelligence through all the degrees of our community, and this process removes from the modern problem of the division between rich and poor some of its worst features.

Taking a long survey over the history of our race, it is difficult to find any indications of a permanently rich stock and a permanently poor stock. The pedigrees of exceedingly few of the greatest of our modern noble families go back to the Wars of the Roses. Indeed, the generality of the highest dignities of our kingdom are creations of the seventeenth, eighteenth, and nineteenth centuries. And it is a notorious fact that a large proportion of our county families owe their apparent ancientness to the romantic imagination which, since the days of Elizabeth, has been a characteristic of our Heralds' College. The fact is, our social structure has a peculiar life and a peculiar process of growth. Only the forms of it are stable; and the individuals that temporarily embody these forms gradually but constantly change their positions in the course of generations.

Let us put it that our community is shaped in degrees, like the structure of a pyramid. At the bottom were once the ancient serfs, originally composed of the Iberian agriculturalists, a race somewhat small in stature, with brown eyes and dark hair. Mingling with them were Britons and Anglo-Saxons, who, by defeat or other misfortune, lost their political or economic freedom. The Danish invasions threw a considerable part of the Anglo-Saxon people into a state of subjection, and the Norman conquest quickened the decline from power of the English tribesmen. Few of even the great thanes were as happy as the ancestor of the present Earl of Plymouth, who managed to hold his lands against the Normans. The upshot was that Iberian, Briton, Englishman, and Dane were at last crushed together and consolidated into the broad, strong base of the pyramid.

It would take too long to trace in detail the various movements of ascension and declination that worked through the social pyramid and brought about a reversal of the positions of serf and aristocrat, trader and noble. It is possible that there were other forces in operation besides the luxury that enfeebled and sterilised the noble

stock, the ambitious cast of character that hardened and sharpened the minds of the trading class, and the slow, steady, indomitable temper of soul with which the peasantry wore down the machinery of oppression.

It is very likely that causes unrecognised in political science helped to set up the ascending and descending currents of change in the social pyramid. For instance, it has recently been found that persons of Iberian characteristics are more resistant to certain diseases than the fair-haired, light-eyed Northern races. They are winning in the urban civilisation of the modern era, by reason of the fact that they are less subject to certain infantile maladies than are the newer elements of the Anglo-Celtic races. So it seems possible that their remarkable strength of constitution may have continually benefited them amid the deadly epidemics and endemical diseases of our islands.

The Mistake of Regarding Social Politics as Involving Class Warfare

However this may be, it is a matter of verifiable fact that poverty and riches, servitude and power, have been individual traits in our civilisation. They have not been class characteristics. They still are not class characteristics. Thus, in an historic view it is misleading to talk in our country of class warfare. What passes for class warfare is only a temporary struggle between temporarily united groups of individuals, some in the ascending movement for the time being, and some in the downward movement. A rich, powerful, and enlightened man of our present generation who engineers some social reform for the welfare of the poorest working class may unconsciously be working for the benefit of, among others, some of his great-great-grandchildren. In the same way, a labour representative who tries to hold a just balance between the national interests of the employing class and the immediate necessities of the working people may be establishing a precedent in legislation from which some not remote rich descendant of his will profit. Of course, these considerations cannot remove from the struggle between the actual classes of our present society all its sectional bitternesses. Individual needs and individual prejudices are bound to animate the disputes between capital and labour, and subtly to inform the political conflict between a declining aristocracy of landowners and a rising plutocracy of financial and industrial leaders. Yet when we are able to recognise that the meek do sometimes manage to inherit the earth, even if they, in turn, become luxurious and overbearing in their period of success, the social scheme takes on a complexion of more justice and more freedom. And especially, seeing that the well-to-do classes of the present day are much less fertile than the labouring populace, we shall not be inclined to agree with Mr. H. G. Wells in his statement that "the gradual widening of the present merely temporary and social difference between the capitalist and the labourer is the key to the whole position."

The Inheritance that Comes at Last to the Working Class Through their Greater Fertility

The epithet of "proletarian," given in scorn to the class that serves the State not with property but with offspring (proles), is really a title to ultimate victory. The man of property in ancient Rome who so stigmatised the poor labourers around him has vanished, but the descendants of those labourers now form a flourishing part of the population of modern Italy. For centuries they have climbed to places of dominion; and possibly it was they who first instituted, in small and scattered industrial centres, the modern democratic movement that is now sweeping through the world. Everything at present makes for impermanence in the social status of the stocks of a society. Only one thing could take away from the working classes the natural advantages they possess over the less fertile propertied classes. And that one thing is a want of proper nourishment. If the base of the social pyramid continually grew weak in actual bodily strength, then nothing but the invasion of a mighty and more virile race could prevent utter decadence.

The Weakening of the Nation Through the Emigration of the Virile

For many years the motherland of the Anglo-Celtic races has been running the risk of this disaster. On the one hand, she has given much of her best blood to her Colonies. From the time at which the United States began to expand by emigration, the drain on the vital resources of the mother country has been so rapid and so large as to be entirely without parallel in the history of mankind. The younger nations have attracted an enormous number of vigorous, alert, and adventurous spirits; and by this process of sifting, nearly all the hopeless, apathetic, shiftless failures in our industrial civilisation have been left to increase on our hands. Then the progress of mechanical invention and industrial organisation has aggravated the condition of the

failures. In a simpler age they might have been able to find useful, humble work that would at least bring them in sufficient food, and enable them to hand on their constitution unimpaired to their children. In many cases they were incapacitated entirely by an accident—a lack of education, a lack of opportunity, a passing blindness to the great changes in industrial affairs. Yet the race was so swift that when they had stumbled they could not recover their place. So they fell out with weak and empty hands, leaving their children terribly handicapped by the defeat of the breadwinner.

A New Danger that Lurks in the Increased Numbers on the Hunger-Line

It is on this section—a portentously large section—of our population that the rising cost of living throws an intolerable burden. It is made up of the unorganised and poorly paid labouring classes—human machines which the inventor will largely displace by mechanical contrivances. Before the industrial revolution, they were mostly spread about the country-side, and engaged partly in handicrafts and partly in agriculture. They have now drifted in considerable numbers to towns and cities, where they maintain a very unequal struggle against the hard and hazardous conditions of their life. They stand on the hunger-line, and respond with terrible delicacy to the real movements of prosperity or want among our people. Very little is needed to compel them to go on half rations. A slight rise in the price of common necessities that is scarcely felt by the ordinary householder means to them semi-starvation. Naturally the children suffer most. For the health of the breadwinner must be maintained as far as possible, or the family goes to ruin and the workhouse. So the children, and the mother of the children, and the baby to which she has not yet given birth, fall a prey to the weakening, sapping vampire of famine.

The Grave Handicap Under Which One-Third of Our Population Suffers

That is to say, the second generation of these labourers of the lower class set out in life with a heavier burden than even their fathers bore. And so the stock decays. If this decaying stock were but a small part of the human-strength of our nation, the problem it presents would still be grave and heart-breaking. But careful observers, employing the most exact methods of study, have come to the awful conclusion that one-third of our urban population is compelled to live below the efficient standard of life. Whether matters are better in rural districts, where meat is rare and dear, but certain vegetables are sometimes abundant, has not yet been clearly ascertained.

Yet there is misery in villages as well as in cities; and it is probable that the suffering and the debilitation due to want of proper food are equal in both cases.

Now, as an affair of pure business, the nation cannot afford to look idly upon this dreadful waste of its human strength. It is flesh and blood, brain and soul, that have made us what at our best we are. What material advantages we enjoy many other races also possess. We won to the front, not because we had a monopoly in coal or iron, but because we were the first to develop the genius for making free use of coal and iron. And some time before our industrial expansion we became one of the chief granaries of Europe, not because we held the richest ground and enjoyed a regular climate, but because we had an original force of mind that could transform our clay soil, with its changeful, hazardous weather, into a land of plenty, with the finest wheat and the finest cattle then in the world. It was the sheer human strength of our people—the strength of their body, the strength of their mind, the strength of their spirit—that enabled them to become the pioneers of the kingdom of man.

The Difficulty of Paying Higher Wages with a Slender Margin of Profit

It is therefore a matter of high, vital, and overwhelming importance to find some way of preventing about one-third of the fund of human strength of the nation from being turned into a source of weakness, degeneration, and bodily and spiritual malady. No doubt a general increase in the wages of the lower-class labourer would save his children from becoming a decaying stock. But it is questionable if the money he receives for the work he now does can in all cases be augmented to the necessary degree. Even when that ultimate weapon in the struggle between the employing class and the working people—the strike—is used, it cannot prevail against the economic forces of the whole world. This is so in trades admirably organised for the battle of wages; and the lower class labourer has yet to learn the lesson of organisation.

Already there are some important branches of our export trade that may be unable to grow under any considerable increase in the costs of production. For

example, the cotton trade of Lancashire, that furnishes one-third of our manufactured goods, brings to the operatives an average weekly wage of not more than twenty shillings. And it is difficult to see how this average sum can be heightened. For a great proportion of the cotton goods of Lancashire is sold to the peoples of the Orient, and, as they are extremely poor, they are unable to give much money for their cotton imports. If the prices are raised, they cannot buy, and they do not pay. Moreover, there are twenty foreign countries manufacturing cotton, and they prevent us from attempting to raise our charges in the markets of the world. And as the average return on the capital invested in our cotton industry is moderate, presenting a narrow margin between prosperity and adversity, the employers would be driven out of business if the average wage were forced up much beyond its present level. So it seems that the Lancashire operatives as a whole can expect, as things are at present, no more than a modest wage, earned by severe and ceaseless effort.

The Strike-Weapon Effective Only Where a Higher Wage-Bill can be Afforded

It would therefore appear that the weapon of the strike, which our working classes have started to use in a fierce and large way, is not generally capable of extorting an increase of wages. It will be permanently effectual only in those industries that can be profitably carried on with a heavier wage-bill than they now pay. Possibly there are many trades, large and small, that can stand a rise in the cost of production, similar to the rise which has taken place in various industries in the United States without seriously impeding the expansion of American exports of manufactured articles. And presumably these trades will be sifted from the others, and become the storm-centres of the new era of industrial warfare on which we have now entered. And wherever some of the new charges for labour can be thrown on the consumer, without playing into the hands of foreign competitors for markets, the consumer will be taxed for the benefit of the worker.

Undoubtedly the employing class will not be able to bear all the burden of a considerable increase of the wages-bill of the country. Some of the new charges will fall upon the native consumer, and this will lead to a further general rise in the cost of living. The workers organised into militant trade unions will not suffer if they are successful in the struggle upon which they have now entered. For it seems very likely that, even where their actual wages are kept down by foreign competition, they will derive some benefit from the schemes of co-partnery which are now attracting public attention. And when all the members of trade unions take an active part in the wonderful co-operative movement, which is growing into a master-force in our country, they will be further protected from some of the disadvantages of the increasing cost of living.

Industrial Victory Purchased at the Expense of the Poorest Labourers

In short, practically all the machinery is ready for the mitigation of the lot of the organised classes of labour. They are much too powerful and much too alert to submit to ultimate defeat. Even from a political point of view, neither of the two great parties in our State can now afford to disregard their claims. It needs only a little more organisation to build them into a third party which would nearly always hold the balance of political power between the Liberals and the Conservatives.

On the other hand, the industrial victories of the trade unionists will be purchased partly at the expense of the low-class labourer who remains unprepared for concerted action. Every increase in the costs of production, every result of the rise in the wages-bill of the country, will aggravate his already heavy misfortunes. If his children were left entirely to his care in these circumstances, there would be a dreadful acceleration in the decay of a large part of the vital strength of our nation. For, even if we allow that the present intense movement of unrest among our working people will incite some groups of still unorganised labourers to array themselves for a struggle for higher wages, yet there will remain a vast number of scattered, casual pickers-up of small jobs, who, from the nature of their employments, will be unable to act together and make their common power felt. It is the children of these men that must be fed and educated and newly equipped by the nation.

The Necessity for State Subsidy Along the Hunger Line

In plain words, we must subsidise the stocks on the hunger-line, in much the same way as some States subsidise certain industries and commercial enterprises.

There is nothing new in this idea. It is an ancient principle of English common law that very poor persons should be sustained by the rest of the nation. A

THE SIMPLE HOMES OF GREAT MEN

A LITTLE GALLERY OF DRAWINGS AND PHOTOGRAPHS ILLUSTRATING THE PLAIN ORIGIN OF MEN OF GENIUS AND DISTINCTION IN HISTORY AND ACHIEVEMENT

BUNYAN'S BIRTHPLACE

SELDEN'S COTTAGE

THE COTTAGE WHERE ROBERT BURNS WAS BORN, AT ALLOWAY, NEAR AYR

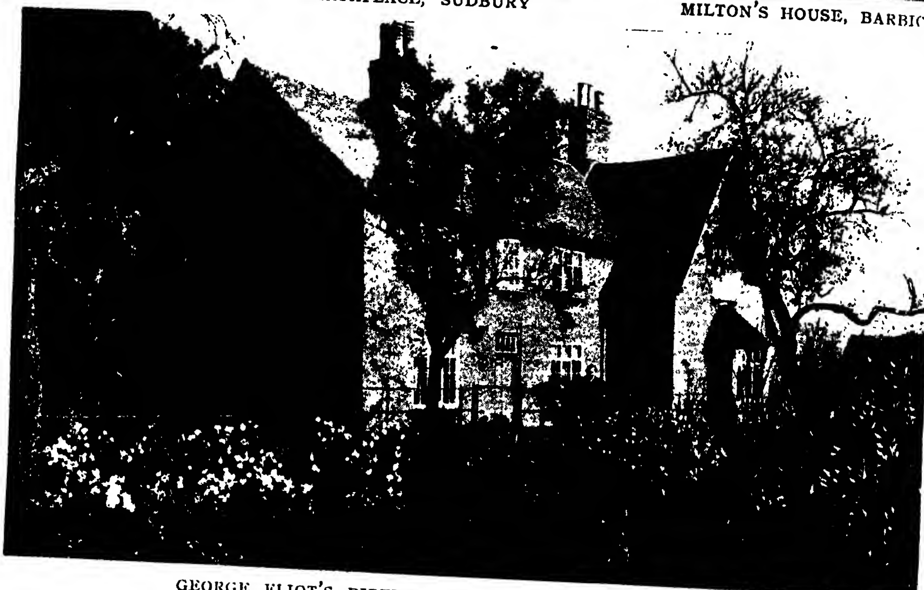
THOMAS A'BECKET'S HOUSE

NEWMAN'S COTTAGE AT LITTLEMORE

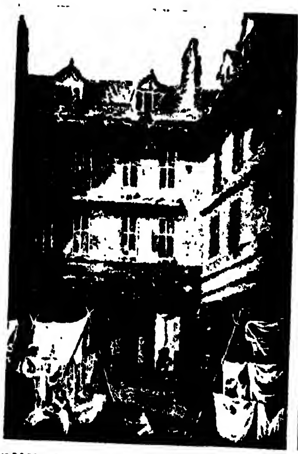
The picture on page 2568 of Stanley's birthplace is reproduced from "The Autobiography of H. M. Stanley," by kind permission of Lady Stanley, and that of Livingstone's birthplace, on page 2567, from "The World's Great Explorers," published by George Philip & Son.

GAINSBOROUGH'S BIRTHPLACE, SUDBURY

MILTON'S HOUSE, BARBICAN



GEORGE ELIOT'S BIRTHPLACE, ARBURY FARM, NUNEATON



ONE OF GOLDSMITH'S HOMES

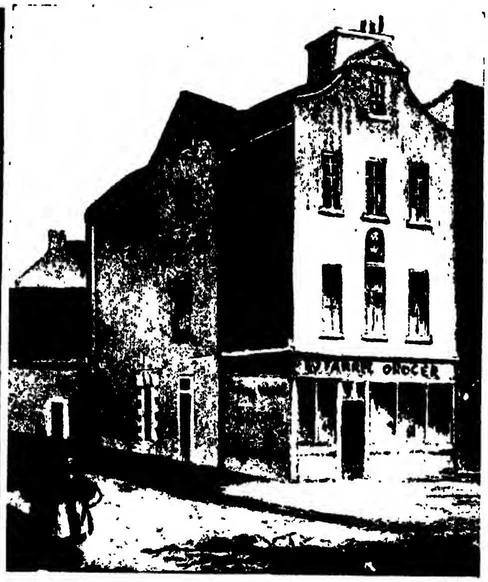
WOLFE'S BIRTHPLACE, THE VICARAGE, WESTERHAM

BIRTHPLACE OF DR. JOHNSON AT LICHFIELD

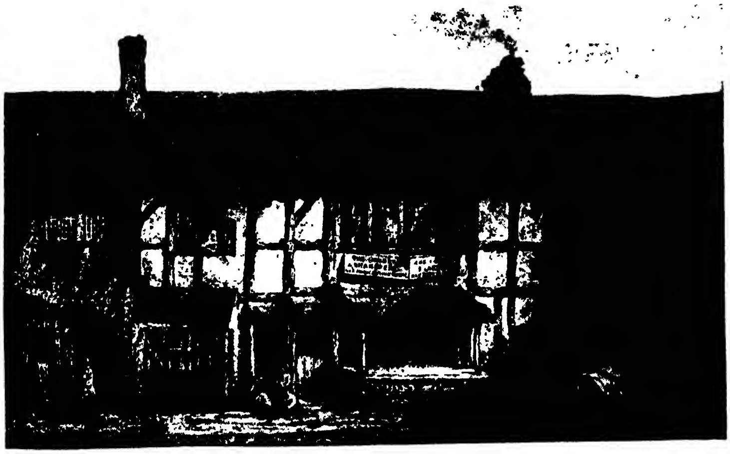
BIRTHPLACE OF DR. LIVINGSTONE

DOVE COTTAGE, GRASMERE, OCCUPIED FOR SEVEN YEARS BY WORDSWORTH, THEN BY DE QUINCEY

BIRTHPLACE OF SOUTHEY



BIRTHPLACE OF THOMAS MOORE



AN OLD PICTURE OF SHAKESPEARE'S HOUSE, STRATFORD-ON-AVON

TURNER'S BIRTHPLACE

THE COTTAGE IN WALES WHERE SIR HENRY STANLEY WAS BORN

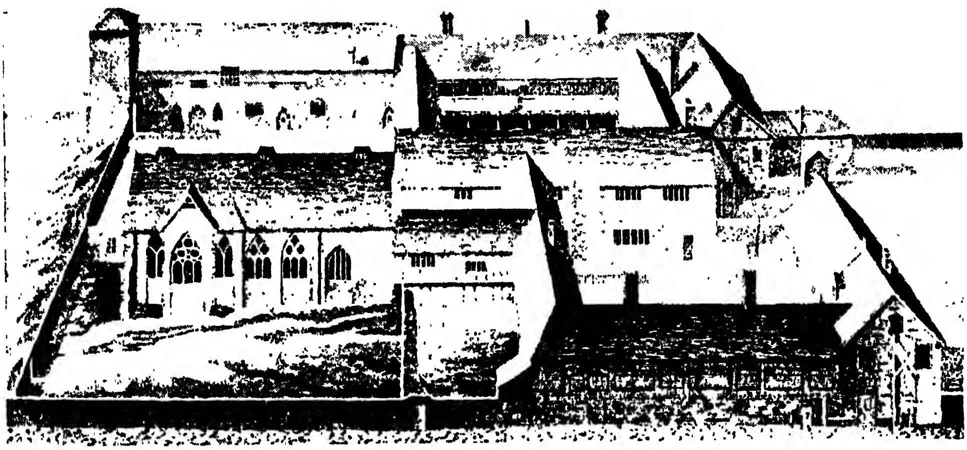
GEORGE STEPHENSON'S BIRTHPLACE AT WYLAM

ADDISON'S BIRTHPLACE, MILSTON, WILTSHIRE

writer in the days of Edward II. states that this right to the necessities of life was in force before the Norman Conquest. Certainly it is now one of the fundamental principles of our society; and the scheme of the Poor Laws, developed on national lines since the Tudor period, is proof of this. We are now spending nearly £18,000,000 every year in providing food and sometimes shelter for about a million bankrupt lives. In addition, there are over 900,000 persons in receipt of old age pensions. So, roughly speaking, two persons in every forty-five are helped by the State.

But, except in the case of the old age pensions, the great national fund used in public assistance is not well spent. For instance, no small proportion of the 600,000 children brought up annually upon outdoor relief are chronically ill-fed, insufficiently clothed, and badly housed; and in thousands of cases they are brought up at the public expense in drunken and dissolute homes. It is a notorious fact that the administration of our Poor Laws is often tragically bad. In spite of a widespread, but yeasty, emotional interest in urgent matters of social reform, there is a general failure to attract capable leaders and leading citizens to the actual task of Poor Law administration. And the public takes no interest in Poor Law work and Poor Law elections. Hundreds of thousands of men and women are ready to talk about social reform, but they will not go even to the trouble of choosing able guardians of the poor. Two Royal Commissions have advocated that a more constructive and helpful use should be made of the vast sums now largely spent in humiliating the very poor, and robbing them of their self-respect. A small but influential group of the last Commissioners went so far as to recommend that the Poor Law system should be entirely destroyed, and then rebuilt on a more far-reaching and effectual idea of public assistance. And though the majority of the Commissioners did not concur in this proposal, they agreed in the abolition of workhouses and the need of a new system of administration.

It comes to this: The money required to reinvigorate the decaying stocks of our people is already provided. The machinery necessary to administer the money so as to increase the human strength of our nation is designed, and could be brought into action in a few months. There is, moreover, sufficient general interest in this side of social reform to create a new army of able and unpaid workers who would direct the new machinery. The only things required are Parliamentary action, and a call from some person of high authority to the eager social reformers of every class, especially to the men and women who themselves have gone through the mill of poverty. But nothing whatever is being done, though it is now some years since the last amazing report on our Poor Laws was published. A savage revolutionary might be pardoned if, looking at the wild and general labour unrest that seems to be shaking the foundations of our State, and contrasting it with the



INSTITUTIONAL TREATMENT OF THE POOR. A FOUNDATION OF TUDOR DAYS

This eighteenth century engraving of Christ's Hospital, Ipswich, represents one of the typical Houses of Correction that were brought into existence in the reign of Queen Elizabeth. The buildings, originally the House of the Black Friars, were purchased by the Corporation. The institution was also used for the instruction of the young and as an asylum for the aged.

Government's apparent indifference to the scandalous need of Poor Law reform, he were to say, "Whom God wishes to destroy, He first blinds."

We must continue to subsidise our working classes. A large proportion of our people already receive grants in aid, for the reason that their wages alone cannot yet bear all the charges of civilised life. It has been estimated that the hospitals and other charitable services to the labouring classes, and the public services they receive from free education, insurance from accidents, and old age pensions amount together to 15 per cent. of the wages-bill of the country. The new scheme for providing medical aid and health insurance to nearly 14,000,000 persons will greatly increase the amount of the subsidy to the working classes. It is worthy of note that leaders of both of our two principal political parties have favoured the extension of national services to a particular class. For example, Mr. Joseph Chamberlain and Mr. Lloyd George vehemently disagreed in regard to the scheme of taxation for raising money for the payment of old age pensions, but they concurred in regard to the main question of establishing some kind of old age pensions. All this goes to show that there is a general agreement that the wages of our working classes have not reached a level equal to the standard of modern civilised life; and if this be so, it behoves all patriotic thinkers to forget Party considerations while they deal with a question vital to the nation, because it affects the people from whom in largest proportion the men of the future will spring.

Our own very rough estimate of the capital value of the public and charitable services rendered to the working classes, including national insurance, is £1,875,000,000.

Hospitals and charities	£11,500,000
Health insurance	12,500,000
Workmen's compensation ..	2,700,000
Old age pensions (about) ..	10,000,000
Education	18,000,000
Poor Law (about)	18,000,000
Roman Catholic charities, employers' loss on half-holidays and holidays, and various undisclosed private services, say, to get a round figure..	2,300,000
Total addition to the national wages-bill	£75,000,000

At twenty-five years' purchase this would come to £1,875,000,000. It is not a small amount, and it represents the value of the services rendered to only one particular class of the community. Surely all that is now needed to preserve the human strength of the stocks from which the lower class labourer springs is a national and well-co-ordinated plan of administering all working class services. And special regard should be had to increasing the physical and mental equipment of the children of the poorest class, and to opening avenues to higher careers for them. The means for doing this have been arranged in outline in several recent Acts of Parliament, including School Medical Inspection, whereby the physical condition of all children should be registered carefully three times during their school career; the Children's Meals Act, whereby, in cases of palpable underfeeding, the community may supplement the food given by the poorest or most negligent parents; and the Choice of Employments Act, whereby, Educational Authorities may interest themselves in finding a suitable permanent occupation for each child when it leaves the school.

INDUSTRIAL PROBLEMS REACTING ON THE CHILDREN—MEAL-TIME IN THE SLUM HOUSE

THE AGES OF PARENTS

A Question Studied but Little, with Confusing Effect, and Demanding Wider and Fuller Investigation

THE IDEAL AGE FOR FAMILY GROWTH

There now arises a very natural and important question on which Darwinism and Mendel's law and the American Eugenists have not said a word—Does the age of the parent affect the quality of the offspring, and, if so, how? The very question is startling, because we have been confidently assuming, all along, that such and such a person would be liable to have such and such children, according to his ancestry, or according to the germ-cells he bore; and though the possible action of the racial poisons upon such an individual has never been left out of account in the present statement of eugenics, it has not occurred to us that the sheer action of time—as we may unphilosophically style it—has to be reckoned with, and that the child of the man of twenty may be different from the same man's child at forty, simply in virtue of the fact that the father's age is different in the two cases.

If such a difference exists, it must be ascertained. Its interest is, or would be, incalculable. It would raise new questions for biology at large, and for genetics, which has never thought of such a thing. It would be, above all, interesting for the Eugenist, who knows that people marry at very different ages, and who has evidence that the age at marriage, in both sexes, is steadily and irresistibly, if slowly, rising. Is this desirable, or undesirable?

It plainly affects the birth-rate, but that is a mere matter of numbers only; does it affect the quality of the children born? Does it mean that we lose the best children—on the theory expressed by George Meredith, when he says, "Glad are the young of youth"—or that we are fortunately spared children who would have been less worth having?

Until we have studied this problem we do not know whether we want people to marry in their early twenties, or to wait until their thirties, or whether, from the eugenic point of view, this is a matter of indifference. And, if the birth-rate must fall, and people will limit their families, we do not know whether it is better for the future that years should elapse before they have their few children, or that they should have their few children when they are young. If we are to lose some, is it better to lose the earlier or the later born?

We owe to Professor Karl Pearson the first study of this subject. His work introduced us to a question which had been ignored, and he showed, beyond dispute, that there was *something* to be ascertained.

If the reader requires definite and final statements on a subject hitherto almost untouched, he must go elsewhere for them; here we can only deal with the meagre but extraordinarily suggestive evidence which science has gathered, and, to the best of the writer's knowledge, that evidence depends upon the work only of Professor Pearson, and Dr. R. J. Ewart, of Middlesbrough.

The problem, as dealt with by the biometricians, was looked at purely from the numerical point of view, which is their strength and their weakness. The question was to ascertain whether the *order of birth*, in a given family, affected the constitution of the offspring. This, we observe, is not the same question as that of the age of parents, but is obviously intermingled with it; and it has a practical and political importance of its own, which may even be of eugenic importance, since the first-born sons, in certain grades of society, are more likely to marry and become parents than are their younger brothers. This problem of the order of birth, which the biometricians tackled, directly affects one of the most widespread and potent of social customs and laws—namely, that of primogeniture.

Now, primogeniture has huge consequences; it affects the marriage-rate, the parenthood-rate, the social influence of the first-born as compared with other sons, and it determines the succession of the monarchy and of any hereditary Chamber.

The biometrical results were startling, contradictory, and in many respects uncertain, but there were, nevertheless, results which showed that the question had been opened once and for all. Those results, even from the point of view of the student of primogeniture, are unsatisfactory, for, though they deal with order of birth, they do not clear up the difference, if any, between the birth of an eldest son when, for instance, the parents were twenty and when they were thirty-five.

Differences Said to be Found Between First-Born and Later-Born Children

The biometricians found very decided differences between the first-born, and also, in somewhat lesser degree, the second-born, members of a family and those who follow them. Generally speaking, and on a first view, this difference appears to be very much to the detriment of the earlier-born, and to involve the gravest scientific condemnation of primogeniture. For the earlier-born children, especially the first-born, were found to be distinctly more liable to feebleness of mind, to consumption, to epilepsy, and such disasters and defects. On the other hand, they were found to be somewhat favoured in the matter of longevity—a conclusion which does not seem to harmonise very happily with their special liability to such a deadly disease as consumption.

But the case becomes more difficult still when we are assured that the elder-born also comprise an exceptional proportion of the brilliant and talented and successful, especially when we remember how many complications of opportunity and favour and circumstance have come into the question before we make our calculations.

The Conditions which Make Order of Birth Alone a False Distinction

Further, a little thought will show how very inadequate, from the point of view of biology, is any reckoning which simply depends upon order of birth. A woman marries in her fortieth year, and has a first-born son. He and his characteristics go down in the statistical tables as those of a first-born. Yet, from the biological point of view, should he not more accurately be reckoned as among the latest of a large family, say, of fifteen or more individuals?

There is a further complication. Fathers and mothers are in a different case in this relation, but the study of the order of birth cannot distinguish between them, for the order of birth is the same for both parents. But the mother's organism has a special, prolonged, unique, exacting ordeal to surmount in each case. Hence, in her case, order of birth may mean something real, wholly apart from the fact that the mother is older when the later children are born. It may mean that the mother's organism is affected by its past efforts of experience, wholly apart from the influence of age or "time," as such, upon it, if such an influence exists. All this must be cleared up. But before all the confusion, dependent upon the lack of distinction between the case of the father and the case of the mother, and upon the other complications cited, has been cleared up, Professor Karl Pearson has already made the suggestion, certainly most hazardous, that the relatively defective character of the earlier-born—which we do not here accept as proved—is due to the "maternal novitiate," and that when the maternal organism has become more accustomed it can produce better results.

Consequences that would Follow if the First-Born were Under a Disadvantage

As the question has thus been left by the biometricians it is in a welter of confusion Thus, let us ignore the contradictions about longevity and so forth, and assume it proved that the earlier-born children are the least desirable, and that this is somehow due to the order of birth and to nothing else—to the "maternal novitiate," in fact. On this assumption, or rather these two assumptions, it is a eugenic demand and a social duty to encourage early marriages and large families, so that we may have as large a proportion as possible of later-born to earlier-born children. The mothers must marry early, so as to get through their inevitable novitiate as quickly as possible, and leave plenty of time for the production of many healthy children afterwards. This is clear, and makes a clear demand, on these assumptions. Women must marry early and produce many children, if they produce any. Further, small families, as such, are entirely objectionable on these grounds. A one-child family, or two-child, consists of nothing but those exceptionally liable to be relatively or wholly undesirable; and even a four-child family will only be about half and half. And the present tendency to have small families, which means a larger proportion of earlier-born children in the next generation (which is simply deprived

(those who would have been the later-born), must be condemned altogether.

This is very alarming and important, and there can be no doubt about it—if we grant the biometricians, first, their assertion as to the elder-born, and, second, their explanation of it. But now suppose that we accept the assertion and consider a different explanation of it—viz., that *sad* "are the young of youth," and not the mother's inexperience but her youth is responsible. On this theory everything changes. The early marriage is now to be reckoned a disaster. Only let us postpone the marriage age sufficiently, and we shall be altogether without those children who are so liable to be diseased or defective, and shall only have those whose chances are better. The size of a family now becomes of no importance. The only essential thing is that the mother —or both parents, for that confusion is still unremoved—shall be old enough. Then they may only have, say, two children, but these will really correspond to children far down in the list of a large family that began when the parents were young, and so all will be well. But, on the "maternal novitiate" theory, all would be ill!

The first necessity is to try to ascertain which of these two factors, age, as such, or the "maternal novitiate," is important, or, if both, exactly how so.

Is there a Desirable Age for Parenthood in Both Sexes?

This can be done, no doubt, by distinguishing between the father and the mother. Let us take the age of the father alone, by comparing large numbers of children, born to fathers of all ages, and then we shall see whether age, as such, matters at all, for in the father's case the obvious complication of the "maternal novitiate" does not arise. Inquiries of this kind have now been made, for fathers and for mothers also, by comparing the children of mothers at various ages, and it seems no longer open to doubt that the age of the parents has a real influence upon the quality of the offspring.

Such a conclusion is of the utmost moment for eugenics. Whatever the facts may be, they must be ascertained. We must ascertain the influence of age upon the father as a father, and upon the mother as a mother. We may not unreasonably find that there is an *optimum* age, more or less capable of definition in each sex, in which parenthood is most desirable from the point of view of the quality of the children. Anyone can see, at a glance, that this question of the age of parents raises the whole issue to a plane of reality and utility compared with that of the order of birth. The order of birth remains the same whether the children be born, one, two, and three, when the mother is respectively 17, 18, 19, or 22, 23, 24, or 37, 38, 39, or 23, 26, 29; but we need only look at those figures to see that order of birth leaves out of account the whole of the problems associated with extreme youth, or elderliness, of the mother, and also the problem of the intervals between the children. In the four notably contrasted cases we have cited, order of birth makes no distinction, but simply classifies the children as one, two, three in each.

Detailed Observations that Have Been Made in Yorkshire

We come, then, to the vital question that underlies all these inquiries—the age of the parents. This has, of course, been studied in the past, and universally legislated upon, from various points of view which are not quite ours.

It has chiefly been looked upon from the point of view of the parents themselves, and especially of the mother, and thus the laws of various countries forbid marriage below certain ages, and obstetricians have often discussed the best age for a girl to marry. These are matters of high importance too high to permit of any confusion in dealing with them. Here, therefore, we definitely concern ourselves with what is substantially a new question: what is the effect of the age of the parents upon the quality of the children? And in this respect Dr. Ewart has lately published some observations, made upon the population of Middlesbrough, which demand the attention of all Eugenists. They have already been alluded to, in another section of this work, in their bearing upon the proportions of the sexes in a community, and here we must look at them more closely from the point of view of genetics and eugenics.

Is there Any Relation Between the Age of Parents and the Sex of Children?

For Dr. Ewart's initial and most surprising observation had to do with no less important and unmistakable a characteristic of the children than their sex. Questions of relative vitality, resistance to disease, intelligence in school, and so forth, may be very interesting, but they are dubious, and each one of them involves complications of nurture; do the earlier children get a better chance because there is more room, or a worse because the parents are ignorant, and so forth. But the actual sex of a baby, whether it is a boy or a girl

when it is born—this is a palpable and definite characteristic which plainly has its origin far back, and all the difficulties of allowing for varying nurture after birth are excluded. The complication of ante-natal nurture may also be excluded, as other biological evidence has proved. The sex of the child is no more a result of ante-natal than of post-natal nurture. It is an inherent quality, dependent upon the constitution of the germ-cells from which it was formed. If we can prove a real and definite relation between the sex of children and the age of their parents, then we can only conclude that the age of an individual somehow affects the constitution of the gametes of which he or she is the trustee; and if the age of the parents can be shown to affect anything so deeply seated as the sex of the offspring we must seriously look to see whether it does not affect other characteristics of no less, or even greater, eugenic importance.

It is difficult to demonstrate the recently obtained results without an alarming use of figures, but a few are essential.

Evidence that Girls Predominate Among the Earliest Born, and Boys Among the Latest Born

Taking the population as a whole we find that males are in excess of females, not only in gross numbers, but also at all age periods, *up to the fourteenth year.* At birth the ratio in England and Wales is 1033 males to 1000 females. But this ratio varies in different times and places.

Something must account for the variations. Some causes are at work which affect the constitution of the parental gametes, throughout the country, or in certain places, so that the population of male to female births varies. Now the question is whether the age of the parents thus affects the constitution of the gametes, so that children born to young parents are more liable to be of a given sex than children born to older parents. If, now, we can show that the ages of parents alter in the course of social evolution in any locality, or in the country at large, we may have the key to the altered ratio of male to female births.

The twenty-sixth or twenty-seventh year of the mother's life, on the average, seems to be a turning-point. The children of mothers of that age are boys and girls in equal numbers. In Middlesbrough, Dr. Ewart's results were most remarkable. For mothers under nineteen, the ratio of boys to girls was 659 to 1000; and for mothers of thirty-five and over, the ratio of boys to girls was 1165 to 1000. The change in the ratio was progressive from the very young to the elderly mothers, the numbers of the sexes being equal in the middle of the period, as we have seen. The fact is most unexpected and astonishing, and raises all sorts of new questions for biology and eugenics. Its consequences for society are no less important. Thus it can be shown that the excess of boys born in our nation every year is due to the births that occur after mothers are thirty-four years old. If there were no birth-rate after that age, the excess of male births would not exist.

The Sex Proportion Equal in the Mother's Twenty-Seventh Year

Observe, further, that according to the returns of the Registrar-General there has been a steady fall in males born per 1000 females during the last fifty years. This would seem to suggest that a large part of the fall in the birth-rate has been due to the non-production of children by mothers at the higher age-levels. They have not produced their possible later children, who would have been predominantly male. Further, as regards any given family, we see that the tendency, as proved by Dr. Ewart, is for the earlier-born to be girls and the later-born to be boys. This statement must not be misinterpreted by those who are unfamiliar with the handling of averages. But it does mean that, the younger the mother, the more likely is her child to be a daughter; and the older she is, the more likely is the child to be a son; and if she be in about her twenty-seventh year, the chances are equal.

The Increasing Birth-Rate from Parents in their Maturity

We are not here immediately concerned with the sociological significance of these facts as they bear upon the proportions of the sexes in any given community. That has largely been dealt with elsewhere, and the reader will see that the death-rate would require to be taken into account; for the fact is that the males die more rapidly, and the excess of male births goes with an excess of females in the later years of life—in fact, after fourteen. The point for us here, who are trying to lay the scientific foundations for our eugenic practice, is that the age of the mother has been shown to affect an important characteristic of her children. This means that the practice of eugenics is proportionately less simple. If we were to expect of it all that the sanguine have dreamed, we should have to concern ourselves not merely with the

marriage of the worthy, and encouragement of parenthood on their part, but with the question as to when their children were to be produced.

If the age of the parents affects the constitution of the children in anything so deeply rooted as their sex, we may expect to find similar influences in other respects; and, indeed, Dr. Ewart has done so. In the course of his inquiry he made out the fact, which might well have been guessed, that the fall in the birth-rate strikes especially the extremes of the reproductive age. Whatever the consequences may be, the fact is that we are now getting the children of parents in their maturity, and the children we are losing are those of very young and of elderly parents. Marriages are delayed and families are curtailed, while the children in between the earlier and later ages are those we get. Among other things, this has the consequence that the excess of boys born over girls is diminishing. But what of the other results? Are they good or evil?

It has been apparently shown that the eye-colour of children tends to vary in some degree in relation to the age of the parents, or, at any rate, of the mother, at their birth. The results are still uncertain, however, and it is to be hoped that Dr. Ewart will devote further attenton to the subject.

Is there Any Relation Between Colour-Inheritance and Moral Qualities?

Doubtless the Eugenist cannot concern himself with the promotion of one particular eye-colour as against another, but there are two notable reasons why he must keep his own eyes on this question. The first is that the Mendelians have found human eye-colour to be transmissible according to the Mendelian law—at any rate, in some respects. If the age of the parents is shown to complicate this question, it may also complicate the now numerous defects and abnormalities which are transmitted according to the Mendelian law.

The second reason is a curious but not unworthy one. The traditional association of red hair with a fiery temper may or may not be sound, but the idea that there may be some obscure but real association between mental or moral characteristics and pigmentation of the skin, hair, or iris is not entirely to be laughed at. Universal belief and assertion are suggestive, Many women, and men also, have definite instinctive preferences and antipathies which assume a relation between a " cold eye " and a hard disposition, and so forth. Professor Punnett has recently suggested that if we are successfully to tackle the great question of the genetic transmission of the moral and mental characters of man, we may best begin by a very careful study of pigmentation, in the hope that some correlation between pigmentation and the subtler characters may be observed, and then we can avail ourselves of the fact that pigmentation is obvious, and can be readily and definitely studied. In short, it is imaginable, in the present state of our knowledge, or ignorance, that the influence of parental age upon the eye-colour of children, as upon their sex—which has mental and moral consequences—may also mean an influence of parental age upon mental and moral characteristics, which are as momentous to the Eugenist as eye-colour in itself is trivial.

The Power of Resistance to Disease in the Offspring of Parents of Different Ages

Dr. Ewart is also engaged upon a study of the influence of the parental age upon what is very roughly termed the child's " vitality," or " constitution," as may be measured, for instance, by its degree of resistance to the various diseases of childhood. We shall not here consider the tables which he has already published, as more analysis is required before results worthy of wide publication can be counted on. But here again it is evident that parental age is not negligible, and that this is a question which will have to be taken into account by Eugenists henceforth. Already it seems clear, when infant mortality is studied from this point of view, that the children of elderly mothers, and of very young mothers, are more liable to die; but so many complications enter into this question that it would be unscientific to attempt to do more than state that observation at present.

The Bearing of the Relative Ages of Parents on the Vitality of Children

It will have already occurred to the reader that there is another complication, ignored by the Eugenists as it at present exists. Not only the individual parents, and their age, but the mutual relation of their ages, have to be considered. The American students have shown us how a marked paternal character may appear in all the children born to one wife, and in none of the children born to another. Similarly, here, the relative as well as the absolute ages of the parents must be taken into account by the really scientific eugenics of the future.

Meanwhile, our ignorance is almost absolute, but Dr. Ewart's figures, so far as they go, tend to show that the children's growth is most rapid and satisfactory when

the parents, at the birth of the children, were, respectively, the father twenty-six to thirty, and the mother twenty-one to twenty-five. The reader had better forget this at once if he inclines to take it as any but a first observation, on not very large numbers, in a direction where no really assured knowledge yet exists, and where more is urgently called for.

The problem before us becomes more difficult than ever when we come to study mental characteristics. Dr. Havelock Ellis has come to the conclusion that first or last children of large families are markedly favoured in their chance of inclusion among the ranks of the great; and his figures are so definite that, for the present, it seems we must accept them. Dr. Ewart justly points out that the difference between genius and good mental capacity is so great that a different rule might apply to each. So far as good capacity at school is concerned, he seems to have clearly shown that the children of mothers at the maternal prime, as we may perhaps regard it—namely, the twenty-seventh year or so—are clearly superior to those of very young or of elderly mothers. So far as the evidence goes, this result may probably be found to stand, and its importance is obvious.

The Relation of Parental Age to Feeble-Mindedness in Children

The inquiry may also be made in another way, by studying the liability to the production of defective-minded children according to the age of the mother. Here, also, it seems clear that the mother in her prime is less likely to produce defective-minded children than the very young mother, or, notably, the very elderly mother. But this last fact reminds us of the problem of Mongolian idiocy, and probably means that the very elderly mother is an exhausted mother. Here, also, the evidence must be greatly extended, but, meanwhile, it confirms the idea that, at any rate so far as the mother is concerned, there is a period of maturity, round about the twenty-seventh year, and that her period of child-bearing should itself find a mid-point somewhere about that time.

Summarising all the evidence he has gathered, Dr. Ewart applies it to two representative families—first, the family of sixty years ago, five in number, spread over fifteen years, from the twenty-third to the thirty-eighth year of the mother, and, second, the family of today, three in number, born in ten years of the mother's life, from twenty-five to thirty-five. What difference in quality will be here associated with the difference in numbers and in the mother's age? Probably the stature of the children born now should be increased; they should be somewhat bluer-eyed; and, for the rest, we had better be careful what we assert, beyond that the numbers of the sexes will tend to be more equal on the whole, though the boys will still preponderate slightly.

There is already a good deal of evidence to corroborate the general outlines of the foregoing, when the third generation is taken into account. Those outlines are, of course, very general. If the reader desires more definite and extensive knowledge, the only possible reply is that so do we all.

The Complication of Eugenic Study by the Problem of Parental Age

The great point is that the question has been opened, and must now be thoroughly studied. Meanwhile, the wise and cautious Eugenist will be all the more chary of laying down the law in directions where our ignorance is so extreme. But we are clearly to understand that the identity and personal characteristics of individuals concerned in our eugenic judgments may not be enough; and that, in our study of social forces, and such phenomena as the fall in the birth-rate, we have to find out not merely where the fall is occurring as regards social class, but also where, in regard to the ages of parents or would-have-been parents. Not only must we separately study the influence of paternal and of maternal age upon the characters of children, but also we must tackle the influence of the various possible matings upon the children—old father and young mother, old mother and young father, parents of equal age, and so on.

The Need for Extended Study of the Effects of Age on the Offspring

If the modern theory of the nature of sex be correct, it is clear that "dominance and recessiveness," as applied to the case of the Mendelian factor or factors of sex, is something which is influenced by the age of the parents; and it is imperative that inquiries as to the influence of parental age should be extended to the lower animals and to plants, where the facts can be so much more quickly and surely ascertained. Meanwhile, we appear to have a provisional conclusion that the *optimum* age for motherhood is somewhere about the twenty-seventh year. But, as we shall see, other questions of no less importance complicate the issue in a society where mating is by substantially permanent and irrevocable marriage, and where the problems of marriage choice at various ages, and of economics, have also to be solved.

COMPANIONS OF THE SUN

What the Most Recent Observations Have Revealed Respecting Mercury and Venus

THE PLANETS INSIDE THE EARTH'S ORBIT

We have already given some consideration to the vast cosmic processes by which our solar system is believed to have come into being. Let us now examine more closely the several planets and their satellites, the asteroids or minor planets, and the comets, meteorites, and shooting stars, which also belong to the system, in order that we may return with more detailed knowledge to a brief review of their entire history. Here, as in all study of Nature, we have to do with amazing unity and amazing diversity. Knowledge of the individual planets has greatly increased within recent years, and has revealed a diversity which was previously quite unsuspected; yet that very diversity has done more than anything else to throw into relief the dynamic and evolutionary unity of the system.

Mercury, the nearest of all the planets to the sun, is for that very reason not easily seen. Copernicus, the founder of modern astronomy, who was the first to lay down the principle that the earth and other planets revolve round the sun as their centre, lamented before his death, in 1543, that he had never been able to catch a glimpse of this innermost planet. Probably the reason for his failure to see it is to be found in the nature of the district where he lived, the low and misty region of Eastern Prussia, where the Vistula flows into the Baltic. Otherwise, one so deeply interested in the planets would certainly have seen Mercury at some time, because twice every year, in spring and in autumn, the planet is clearly visible for several days, appearing as a brilliant star of the first magnitude.

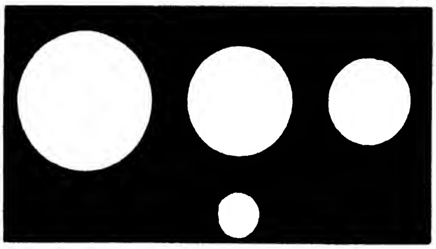
In spring it is seen early after sunset near where the sun has gone down, and must itself set within two hours after the sun. In autumn, on the other hand, it is a morning star, appearing as the forerunner of sunrise. Mercury has been known from the earliest times, and because of its appearance sometimes in the east and sometimes in the west, it was from the first very naturally regarded as two separate stars, a morning and an evening star, and was thus represented under two names in the mythologies of Egypt, India and Greece.

In spring, which is the more convenient season for watching it in Britain, Mercury is first observed very soon after sunset. Night after night, when the twilight deepens enough to show the stars, it is seen to appear higher in the sky, and night after night it increases in brilliancy. Then the contrary process sets in; night after night Mercury follows the sun more quickly over the horizon, and at the same time its lustre diminishes. The course of its autumnal appearance as a morning star is closely similar; at first it is not very brilliant, and is seen very shortly before sunrise; then it gains in brightness and appears daily earlier before the sun; and then the process is reversed—it approaches the sun and becomes fainter day by day.

It is only to the unaided eye, however, that Mercury is thus invisible except in spring and autumn. By means of the telescope this planet, like other luminaries, can be seen all round the year, and high in the sky in broad daylight. The telescope shows also that the disc of Mercury has phases like those of our moon, increasing from a thin crescent to a full circle, decreasing again to a crescent, and then disappearing altogether when the planet is nearly between the earth and the sun. Mercury and Venus, being within the earth's orbit, are alone among the planets in showing these phases; we see the discs of the outer planets always fully illumined. The mean distance of Mercury from the

sun is 36,000,000 miles; at perihelion, or the nearest point of its orbit to the sun, it is 28,500,000 miles away from him; and at aphelion, or the furthest point of the orbit, the distance between Mercury and the sun is 43,300,000 miles. Mercury has, therefore, an orbit which is far more elliptical than that of any other planet. The orbits of the other planets are indeed elliptical, yet their departure from the circular form is so slight as to be hardly, if at all, recognisable in a diagram. But a diagram of Mercury's orbit departs widely from the circular form.

The eccentricity of the orbit is so great that sometimes Mercury is only two-thirds as far from the sun as it is at other times. In consequence, the diameter of the sun's disc, as seen from Mercury, must vary greatly. That diameter, as seen from earth, is 32′; but from Mercury it varies from 67′ at aphelion to 104′ at perihelion. That is to say, the sun's disc as seen from Mercury has at least more than four times the area, and at most more than nine times the area, that it has when seen from earth; and consequently the heat received by Mercury must exceed from four to nine times that received, area for area, on the earth's surface.



SUN FROM MERCURY AND THE EARTH

The comparative sizes of the sun's disc, as seen from Mercury at its least, mean, and greatest distances, and also (below) as seen from the earth.

Mercury completes its orbit in almost exactly 88 days, so that this planet runs through rather more than four of its years to one of ours. The velocity of its movement along its orbit varies considerably, according to its distance from the sun. Thus, Mercury travels at 23 miles per second at the remotest part of its orbit, but attains a speed of 35 miles per second where its path lies nearest to the sun. The mean velocity is 29 miles per second, and at that rate Mercury moves through the distance of its own diameter in about two minutes. The distance of Mercury from the earth varies from 50,000,000 miles, when the planet's disc has an apparent diameter of 13″, to 136,000,000 miles, when the diameter of the disc decreases to $4\frac{1}{2}$″.

Mercury was long supposed to rotate upon its own axis about as fast as the earth does, and so to have a day of about twenty-four hours. But Schiaparelli, who was the first to undertake the systematic study of the planet during the hours of daylight, discovered by watching the markings on its surface that Mercury's day extends to 88 of our days. In the case of this planet, therefore, the day and the year are of equal length.

As our moon rotates once on her own axis in the course of her revolution round the earth, so that she keeps always the same face turned towards us, so Mercury always presents the same face to the sun. The cause of the fixed aspect is in both cases the same. The tides raised in Mercury by the gravitation of the sun have long ago by their friction brought to an end the planet's rotation relatively to the sun. One hemisphere of Mercury is therefore exposed incessantly to the fierce heat of the sun; the other hemisphere is for ever exposed to the frigid night of outer space. Yet, as in the case of the moon, so there is in Mercury also a belt of land on either side, lying between the hemisphere of day and the hemisphere of night, where there are alternate day and night, sunrise and sunset.

This narrow belt, about $23\frac{1}{2}°$ in width, of changing light and darkness, is due to the highly eccentric form of the orbit. In order that the planet might keep always exactly the same face to the sun, while pursuing such an orbit, it would have to rotate at varying speeds upon its own axis, turning now somewhat slower and now somewhat faster. But the speed of its rotation being constant, its face is turned not always absolutely to the sun, but sways now slightly forward, along its orbit, and again slightly backward. The axis about which Mercury rotates is not inclined to the plane of its orbit, as in the case of the earth, but is vertical. The planet therefore has no seasons, except such as may be caused by the wide variation in the apparent size of the sun's disc we have already mentioned. Mercury has a diameter of about 3400 miles. It is not accompanied by any satellite.

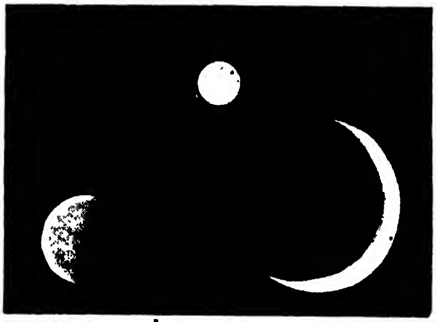
The phases of the planet are not visible to the unaided eye; the telescope is needed to enlarge the brilliant point of light into an image of disc or crescent. With a powerful instrument and good atmospheric conditions, the terminator, or line separating the bright from the dark portion of Mercury's globe, is seen to be very irregular, as it is

in the moon, showing that Mercury's surface, like hers, is highly mountainous.

Mercury shows no trace of an atmosphere, the bright and dark portions of the disc being sharply separated without any twilight. In this respect, as in others, Mercury resembles our moon in being a dead world. Its surface is closely comparable to that of the moon with regard to their respective power of reflecting light. As a reflector, Mercury is far inferior to Venus.

The markings on the face of Mercury, which have been minutely studied and mapped by Professor Lowell at his observatory at Flagstaff, Arizona, are very definite, and have a remarkably geometrical appearance. He suggests that "they seem to mark a globe sun-cracked. At such a condition the curious criss-cross of dark, irregular lines certainly hints, accentuated and perfected as it is by a bounding curve where the mean sunward side terminates. Though they cannot probably be actual cracks, however much they may resemble such, yet they may well owe their existence to that fundamental cause."

The transit of Mercury or of Venus is the passage of the planet between the earth and the sun, so as, from our point of view, to cross the face of the sun.


MERCURY AS SEEN AT ITS GREATEST, MEAN, AND NEARLY ITS LEAST DISTANCE

Of course, only these two planets, having orbits within that of the earth, can ever pass over the sun's disc. If Mercury's orbit were in the same plane as that of the earth there would be three transits in the year, because the inner planet revolves four times round the sun in a year, while the outer planet revolves once round the sun in the same direction. But the orbit of Mercury is inclined by about seven degrees to the ecliptic—that is to say, to the plane of the earth's orbit; and Mercury therefore crosses the ecliptic twice in eighty-eight days, but is usually either above or below that plane. A transit of Mercury can only take place when the planet is between the earth and the sun, and happens also to be crossing the ecliptic. These two conditions coincide from time to time at unequal periods, as follows—three years, ten years, three years; thirteen years, seven years, ten years—and then the same cycle recurs again and again indefinitely. Thus recent and coming transits of Mercury are in the years 1878, 1881, 1891, 1894, 1907, 1914, and 1924.

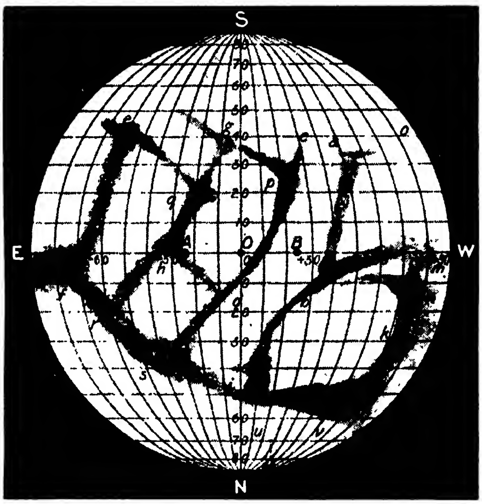
All transits of Mercury are either in May or in November, the next two after the present date being those of November 6, 1914, and May 7, 1924.

The transit of Mercury was first foretold by Kepler, in 1627, for November 7, 1631; and a few hours after the moment which Kepler had predicted, Gassendi, the French philosopher and mathematician, watching an image of the sun projected into a dark room, saw the black globe of the planet entering upon the sun's disc. Since that date the transits of Mercury and of Venus have been carefully observed as astronomical events of the first importance. Their scientific value is manifold. They afford an opportunity of checking very exactly all calculations with regard to the orbits of these planets; special observations may be made of the dark planetary globes when silhouetted against the brilliant background of the sun's image; and the transit of Venus in particular has been made the basis from which all measurements of distance within the solar system have been calculated.

Like Mercury, the planet Venus is at times an evening star, appearing after sunset, and at other times a morning star, appearing before sunrise, and was therefore known in antiquity under two names, Hesperus and Phosphorus. Like Mercury also, as an evening star it rises higher night after night, increasing in brilliancy, and then returns night after night towards the sun; and as a morning star it daily precedes the sunrise by a longer interval, and then daily this interval diminishes again. But its orbit is much larger than that of Mercury, so that Venus may rise as long as four hours before the sun, and set four hours after him.

After the sun and moon, Venus is by far the most brilliant luminary in the heavens. At its brightest it is more than fifty times as bright as any other star in our sky; it throws by night a distinct shadow; and by day, if one knows where to look for it, and the atmosphere is favourable, Venus may be seen with unaided vision in full daylight.

Being within the orbit of the earth, Venus has phases like those of Mercury and the moon. These phases are invisible to the unaided eye, to which the planet always appears as a point of light, but they may be seen with a telescope of no great power. They were among the first discoveries of the telescope, having been seen by Galileo in September, 1610. Anxious to secure the merit of the discovery without risking his reputation by publishing before he had made sure of it, Galileo sent out an anagram, the letters of which could be transposed into a Latin verse announcing the phases of Venus. The phases are best studied in daylight, because of the great brilliancy of the planet by night. Venus is very much larger when seen as a crescent in that part of its orbit which is near to earth than when seen as a full disc at the other side of its orbit. At its extreme distance the disc has a diameter of nine seconds, but at its nearest point the crescent has a diameter of over sixty seconds. This extraordinary variation in its apparent size is accounted for by the great difference between the distances from earth to Venus when the latter is at the nearest and at the furthest points of its orbit; when nearest to earth, Venus is 25,000,000 miles away, but when furthest it is at a distance of 160,000,000 miles.



THE MARKINGS ON MERCURY

The orbit of Venus is very nearly circular, and has almost no eccentricity. The planet revolves about the sun once in about 224 days—that is to say, in about seven and a half months. Venus is very nearly the same size as the earth, having a diameter of 7630 miles as compared with earth's diameter of 7918 miles. The axis about which Venus itself rotates is almost vertical to the plane of its orbit. In the seventeenth and eighteenth centuries it was reported again and again that Venus had a satellite, but as no evidence of this moon has been seen with the far more powerful telescopes of later date, it is believed that these earlier accounts were due to imperfections of the instruments then in use, or to want of familiarity with certain optical illusions, or "ghosts," which are incidental to all telescopic observation.

The planet Venus has an atmosphere to which by far the greater part of its brilliancy is due. Evidences of this atmosphere are manifold. Thus twilight, which is always and everywhere due to atmosphere, is seen along the inner curve of the planet's crescent, and prolongs the points or cusps of the crescent beyond the semicircle. Spectroscopic examination of the planet's light shows the spectrum of sunlight, together with absorption lines due to its passage through an atmosphere not apparently differing greatly from our own, and apparently also including in the resemblance the presence of water-vapour.

On the occasions of its transit, when Venus enters upon the sun's disc, the outer portion of its dark globe, which has not yet crossed the edge of the sun, is plainly outlined by a ring of light, due to refraction of the sunlight by means of the planet's atmosphere. From the extent to which it refracts light, it has been estimated that the atmosphere of Venus is nearly twice as dense as that of earth. But the most remarkable evidence of this atmosphere is shown when the planet approaches what is known as inferior conjunction, that is to say, the point of its orbit at which it is between the earth and the sun. If it should happen at the same time to be on the plane of the ecliptic, it will then of course, cross the sun's disc, and be visible as a black globe. But in the great majority of cases, when Venus is in inferior conjunction, it is either above or below the ecliptic, and would thus be invisible, as the new moon is invisible, except for the presence of an atmosphere. When followed by the telescope to this position, the crescent of the diminishing Venus becomes narrower and narrower, and then flows right round the dark disc, so that the entire profile of the planet is outlined by a ring of sunlit atmosphere.

Just as the unilluminated disc of the moon, usually invisible within its crescent,

is often seen to gleam faintly with earth-reflected light, presenting the appearance known as "the old moon in the young moon's arms," so the dark portion of the disc of Venus sometimes shines dimly with a light which cannot be derived immediately from the sun, showing a pale, ashy gleam over all the surface which is embraced by the vivid silver of the crescent.

This appearance is not easily explained, but there is no lack of theories intended to explain it. Observing that this faint illumination of the night side of Venus has sometimes a violet tinge, and that the years in which it has been most noticed have corresponded to some extent with those in which the aurora borealis has been exceptionally active on earth, some have persuaded themselves that we witness from time to time displays of the aurora in Venus. Others consider that the general light of the stars, reflected from the clouds and atmosphere of Venus, is sufficient to account for this ghostly glimmer.

Others, again, have boldly suggested some kind of phosphorescence of the planet's surface. Newcomb has pointed out that the phenomenon is only seen in the daytime or in bright twilight, and rarely or never after dark, and dismisses it as due to some unexplained optical illusion. "Such an illumination," he says, "would be far more easily seen by night than by day, because during the day an appearance easily seen at night might be effaced by the light of the sky. If, then, the phenomenon is real, why is it not seen when the circumstances are such that it should be most conspicuously visible?"

Professor Lowell, believing for other reasons that the night side of Venus is covered with ice, applies that theory to explain its elusive glow. "If the night hemisphere of Venus," he suggests, "be one vast Polar sheet, we have there a substance able to mirror the stars to a ghostlike gleam which might be discernible even from our distant post." So we have free choice of conjectures in the matter.

THE LIGHT WITHIN THE CRESCENT OF VENUS

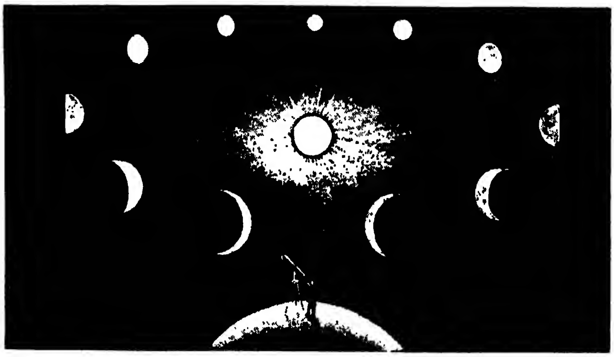
The extraordinary brilliancy of the planet's illumined surface is more easily accounted for. Venus is so near the sun as to receive about twice the amount of light on its surface that we receive on earth; it is also near to the earth, so that the reflecting surface is large from its proximity. It is at its brightest not when the disc is fully lighted, at the opposite side of its orbit, but when the planet has approached so near the earth that its illumined crescent occupies only one-fourth of the area of the disc. But the brightness of Venus is chiefly due to the nature of the reflecting surface. Area for area, Venus is five times as bright as Mercury, although Mercury is far nearer to the source of light.

It is estimated that Venus returns more than nine-tenths of the light which falls upon its surface, being thus an even more perfect reflector than white clouds, which reflect little more than seven-tenths of the light which they receive. This unusually effective reflecting surface is the planet's atmosphere. It was formerly believed that Venus was wrapped in an envelope of clouds, and that these gleamed in the sunlight with such brilliancy as to distinguish this planet above all other stars for brightness. But it is now known that, bright as they are, clouds are yet not nearly bright enough to give the reflected light which we receive from Venus.

It was believed until recent years that Venus rotated on its own axis in somewhat less that twenty-four hours, and this view was supported by observations which appeared to be very exact, though more recent study seems to overthrow them altogether. As early as the seventeenth century, Cassini distinguished a bright spot on the planet's surface, and, following its movements, concluded that the day of Venus was of nearly the same length as the terrestrial day. Towards the end of the eighteenth century Schröter devoted long study to this subject, and came to a similar conclusion. He found that one of the points of the planet's

crescent was blunted at intervals of rather more than twenty-three hours, and considered that this effect was due to the daily return of some mountainous elevation to that point. Again, in the nineteenth century, the same period of rotation was affirmed by De Vico, on the basis of a study of certain markings which he thought he observed on the face of Venus, and their apparent daily movements.

But many expert and well-equipped astronomers were never able to distinguish definite and permanent markings of any kind, and were inclined to agree with Herschel that Venus was wrapped in clouds which hid the features of the surface and prevented any trustworthy observations of its rotation. It is now fairly certain that both of these views were mistaken. Venus does not rotate in a way which is at all comparable to that of our earth, and the astronomers who witnessed that rotation were unconsciously influenced by what they expected to find. On the contrary, Venus, like Mercury, turns always the same face to the sun, so that its day is co-extensive with its year. Nor is the atmosphere of Venus cloudy, but, on the contrary, it is brilliantly clear.



THE VARYING PHASES OF VENUS AND MERCURY

Schiaparelli, who discovered the fixed aspect of Mercury, discovered that of Venus also. Finding certain definite markings on the planet, he watched them intently day by day, and found that their position remained constant, or so nearly constant that the period of the rotation of Venus could hardly be shorter than the period of its revolution round the sun. Similar observations, made by Professor Lowell and his assistants in Arizona, not only confirmed Schiaparelli's conclusions, but threw new light on the markings of Venus. The planet was examined under better conditions of observation than ever before, with the result that the details of its surface came out with unprecedented clearness. Instead of isolated points, distinguished by their greater brightness or darkness from the surrounding surface, Venus now showed a very remarkable system of faint but perfectly definite and constant straight streaks, or lines, across its face, in a notably geometrical arrangement. By observation of these, it was soon possible to affirm conclusively that the period of the planet's rotation on its own axis coincides precisely with the period of its revolution round the sun. The constancy of the markings showed, further, that they are not forms of cloud, and their clearness revealed that Venus is not, as had been thought, wrapped in a cloud-mantle.

The most characteristic markings are radial streaks which run inwards from the circumference of the planet's disc toward its centre; they are broad and definite at the circumference, but become fainter, narrower, and less clearly defined as they converge. Professor Lowell interprets these streaks in a very remarkable way. He believes them to be marks of wind currents in the atmosphere. Venus incessantly presents one face to the sun and the other to the frigid night. "One face baked for countless æons, and still baking, backed by one chilled by everlasting night, while both are still surrounded by air, must produce draughts from the cold to the hot side of tremendous power. A funnel-like rise must take place in the centre of the illuminated hemisphere, and the partial vacuum thus formed would be filled by air drawn from its periphery, which, in its turn, would draw from the regions of the night side. Such winds would sweep the surface as they entered, becoming more superficial as they advanced, and the marks of their inrush might well be discernible even at the distance we are off. Deltas of such inroad would thus seam the bounding circle of light and shade."

The theory is ingenious, but it would be more convincing if there were not other linear markings, not differing in appearance, which do not follow the radial direction. These tremendous wind currents, however, must continually sweep the surface of Venus, and it is difficult to resist Professor Lowell's further conclusion that their effect will be to take up all the moisture on the sunward

side of the planet and deposit it in the form of snow and ice upon the dark side. Or, rather, that must have been their effect in the past, for the process was probably completed ages ago. Again, the incessant hurricanes, driving over the arid regions exposed to the sun's heat, are presumably laden with dust, which may partly explain the dark shading of the radial markings, and partly explain also the intense efficiency of the planet's atmosphere as a reflector of light.

Like the planet Mercury, though much more rarely, Venus crosses the face of the sun. As we have seen, it completes its annual revolution in 224 days, but the earth is revolving round the sun, though more slowly, in the same direction; so that Venus is in inferior conjunction—that is to say, comes between the earth and the sun only once in every 584 days. Transits of Venus would therefore occur once in about every nineteen months, if Venus were always in the plane of the ecliptic. But the plane of its orbit is inclined by more than three degrees to the ecliptic, so that when the planet comes into inferior conjunction it is generally either above or below the ecliptic. Four times, however, in every 243 years Venus is at the same time on the plane of the ecliptic and in inferior conjunction with the sun, and there is a transit.

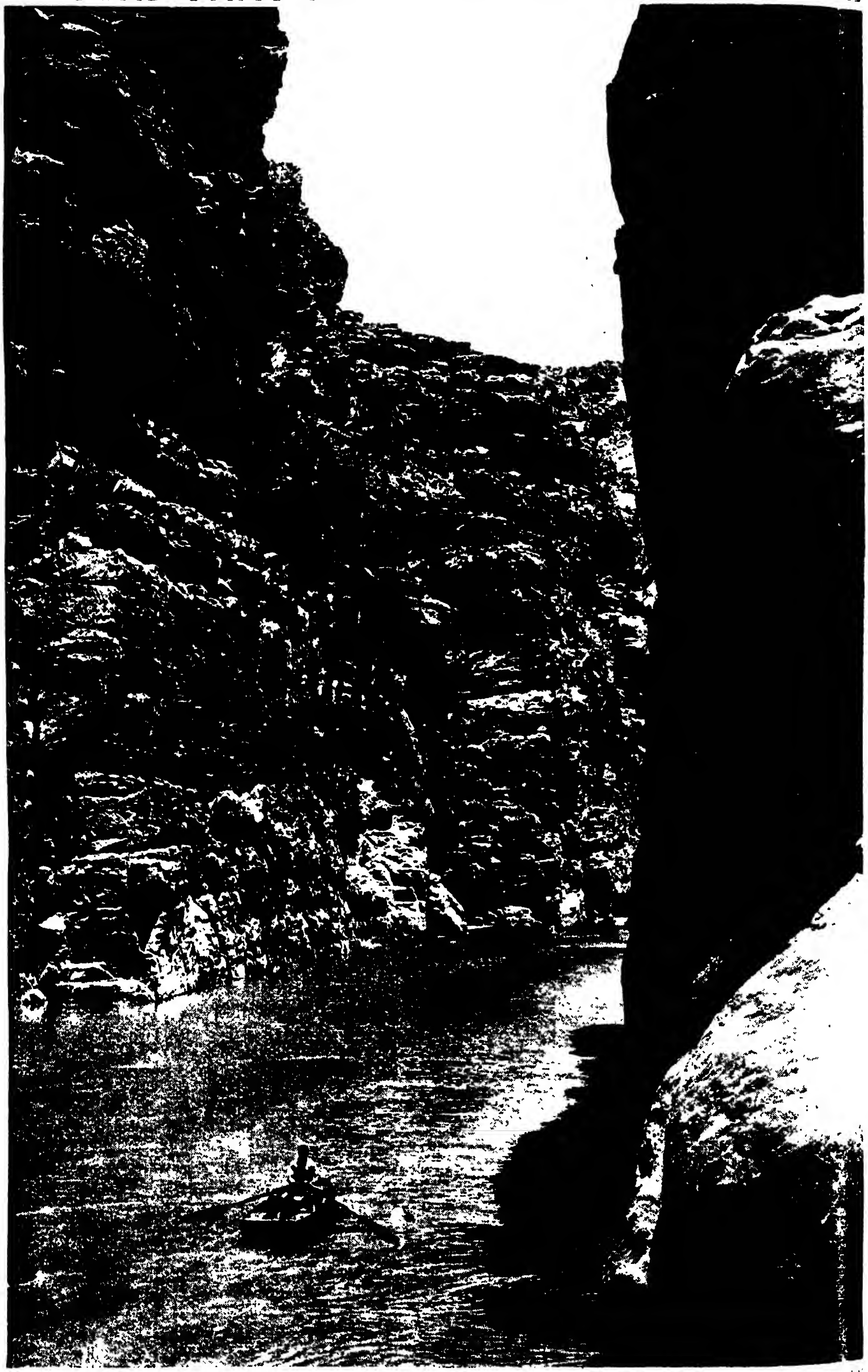
AN IMAGINARY LANDSCAPE ON THE SUNNY SIDE OF VENUS
According to Professor Lowell, this side of Venus has a surface cracked by heat, and swept unceasingly by wind and dust storms of appalling velocity.

These transits take place at irregular intervals, namely, 121½ years, eight years, 105½ years, eight years, after which the cycle is again repeated, and so on indefinitely. It will be noticed that the first period is equal to the sum of the other three. A transit of Venus is plainly a rare event; there is none within the present century; the last took place on December 6, 1882, and the next will be on June 8, 2004. All transits of Venus occur in June or in December.

The transit of Venus must always remain an astronomical event of great interest, and no less care will be given to its observation in the future than in the past. But it has not now quite such unique importance as it used to have, because more exact means have been devised for determining the distance of the sun from the earth. Thus, the effects of the sun's gravitation upon the moon, and again the time which light takes to travel from the sun to the earth, are now used for the calculation of the sun's distance from us. Before these methods were thought out, however, astronomers were dependent principally upon the transit of Venus for this very important measurement; and the transit has been used to obtain it, and will doubtless so be used again, in the following way.

Let us imagine that two observers, one of whom is situated as far north as possible on the earth's surface, and the other is situated as far south as possible, are watching the same transit of Venus. It is obvious that the northern astronomer will see Venus sail across the sun's disc along a lower line, and the southern astronomer will see it cross higher up the disc; and, of course, these two lines will be parallel to one another, and near together, on the sun's disc. One of these lines will be longer than the other, because it will cross the disc at a wider part. Viewed from one of the stations on the earth, the transit of Venus will occupy a longer time than it will occupy when viewed from the other station. From the difference of the periods which the transit has taken at the two stations, together with a knowledge of the distance between the two stations, it is possible for mathematicians to calculate the distance of the sun from the earth.

In order to observe the transits of Venus in 1874, and again in 1882, astronomical expeditions were sent out by all the more advanced nations to every part of the world from which these transits could be seen, but with only partial success.



THE ENTRY OF THE ARNON INTO THE DEAD SEA THROUGH THE CUTTING IT HAS MADE IN THE CL[illegible]S

RIVERS AS SCULPTORS

Rivers Above and Below Ground; Their Cutting and Carrying Powers; What They Destroy and What They Build

MOUNTAINS LEVELLED TO MAKE NEW LANDS

We have already shown that the waters that are under the earth give birth to springs, and that springs often give birth to rivers. But the waters that are under the earth are often full-grown rivers in themselves, and run, as

> Alph the sacred river ran,
> Through caverns measureless to man
> Down to a sunless sea.

This we might guess, for inexhaustible springs discharging millions of gallons a day must have rivers of water somewhere behind. But it is not merely a matter of guessing, for, from all time, subterranean rivers have been known, and from all time they have appealed to the curiosity and imagination of mankind.

> Divine Alphæus, who by secret sluice
> Stole under seas to meet his Arethuse,

was no doubt a fancy founded on fact; while Virgil's description of the Timavus is a description of the real subterranean River Timavo, which flows into the Adriatic Sea not far from Trieste.

As might be expected, subterranean rivers are most plentiful in calcareous countries; but all over the world they appear. Sometimes they gush out of the ground far inland; sometimes they are unseen till they fall into the sea from the face of some cliff; sometimes they enter the sea below sea-level. Near old Fort Kalmath, in Southern Oregon, a large river springs right out of the ground; and from the base of Kilimanjaro, in Central Africa, more than one subterranean river rises. In Syria, we have the Nahr-el-Kelb issuing full grown from mighty caverns. In Greece we have the Stymphalus, which plunges underground and does not emerge again for twenty miles or more. But we need not go so far afield for examples. St. Winifred's Well, in Flintshire, gives exit to a river; various subterranean streams flow into Lough Corrib, in Ireland; and the Peak Cavern, at Castleton, in Derbyshire, has its own underground river.

One of the most beautiful and most famous of subterranean streams is the Sorgues of Vaucluse. In flood, its stream flows at the rate of about thirty cubic yards a second, and quite fills its cavernous exit, but when its waters are low it is possible to penetrate underground and inspect "the vast basin which the blue waters of the subterranean stream spread out before they leap into the open air." The river runs for at least ten miles underground, and on its exit it divides into numerous channels, which irrigate more than seventy seven square miles of Provence.

The region of the Carniolan and Istrian Alps, on the eastern shores of the Adriatic, is famous for its caves and underground rivers. It is to this region that the Timavo which we have already mentioned, belongs From this region, too, several subterranear rivers flow into the Adriatic below low-water level, and one, the Trebintchitza, can be easily seen entering the sea about a yard below the salt-water surface. Here, too, near Adelsberg, we find the River Poik, which pursues a subterranean course for five or six miles under a mountain.

The calcareous shores of the United States are penetrated by various subterranean rivers, some of which undoubtedly flow underground for great distances. Off Florida, in 1857, there was a remarkable discharge of fresh water into the sea. Reclus states that "Muddy and yellowish water furrowed the straits, and myriads of dead fish floated on the surface and accumulated on the shores. Even in the open sea the saltness diminished by one half, and in some places the fishermen drew their drinking-water from the surface of the sea, as if from a well. It is affirmed by all those who witnessed this remarkable

THE WHITE FOAMING RAPIDS BELOW NIAGARA FALLS

inundation of the subterranean river that, during more than a month, it discharged at least as much water as the Mississippi itself, and spread over all the strait, thirty-one miles wide, which separates Key West from Florida." When we hear a story of this kind it makes us wonder how much the Gulf Stream may be augmented by unknown submarine rivers.

There is no feature of natural scenery that so effectively combines the sublime and the beautiful as cataracts and waterfalls. The white water thundering down precipices or dancing over rugged rocks is a spectacle that appeals even to the dullest imagination. But with waterfalls as features of natural scenery we shall deal later, merely pointing out here that it is not the precipice that makes the waterfall so much as the waterfall that makes the precipice.

Let us now look for a little at the work of rivers. It might seem at first sight that the work of rivers is small compared with the work of the sea. The sea is dramatic in its wrath; it wrecks armadas, it tears down cliffs, it inundates cities, it corrodes away continents; it is deeper in places than the Himalayas are high, and it is vaster in its area than all the dry land of the world; while rivers, as a rule, are merely silver threads running across islands and continents, brawling a little as they tumble down hill, but placid and undemonstrative in their meandering course across the plains. And yet the work of rivers is far mightier than the work of the seas, and at times is dramatic enough.

The destructive power of rivers is proved by their mineral contents. The amount of mineral matter in any river varies, of course, with the force of the river, and with the mineral nature of its bed. Thus the Möll, a mountain stream flowing from a glacier over crystalline schists, contains only 2·61 parts of mineral matter in 100,000 parts of water; and the Aberdeenshire Dee, flowing over rocks almost entirely composed of silicates contains only 3·12 parts in 100,000. The Thames, near Ditton, on the other hand, contains as much as 27·20 parts of mineral matter in 100,000; and, as is well known many rivers in flood are chokefull of mud and sand. The mineral contents of an average river of Western Europe, under ordinary conditions, have been calculated as about 21 parts of minerals in 100,000 parts of water.

These figures are too abstract in themselves to give much idea of the amount of solids borne away by rivers; and interesting

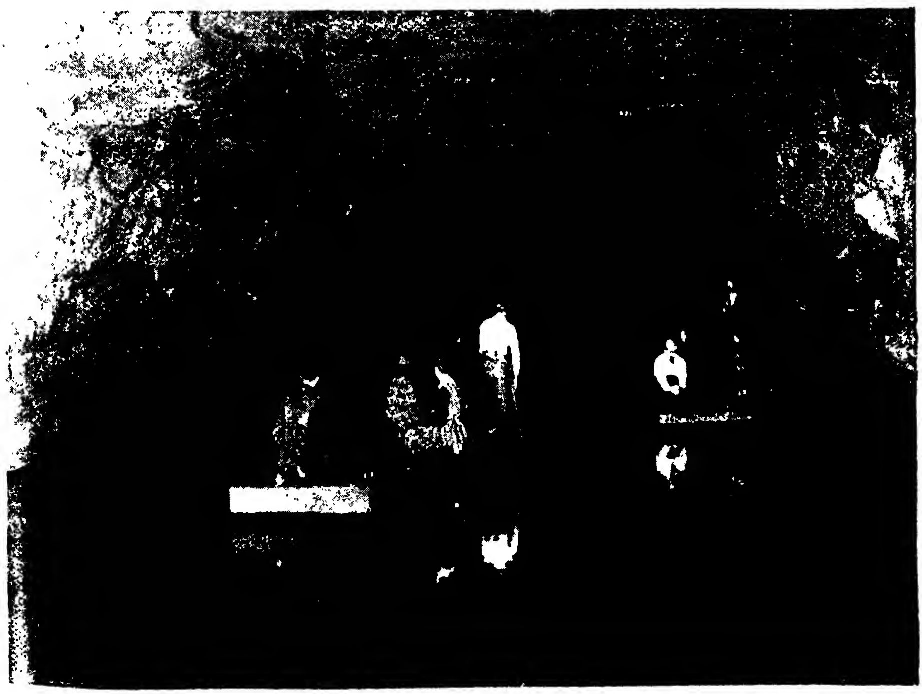
attempts have been made to depict more correctly the destruction wrought by rivers. Bischof estimated that the Rhine carries annually into the sea enough carbonate of lime to make three hundred and thirty-two thousand millions of oyster-shells of the usual size. It has been calculated that every year the Thames removes 140 tons of carbonate of lime from every square mile of the limestone areas of its basin, and that in the course of a year there passes under Kingston enough carbonate of lime to cover the area of Westminster Abbey with "a solid mass of limestone nearly nine feet high."

The Elbe, again, has been calculated to carry away mineral matter at the rate of 48 tons per square mile yearly; the Rhône, at Avignon, 232 tons per square mile; the Mississippi, 120 tons. The Ganges and Brahmapootra bring down annually in the Bay of Bengal about 40,000,000 cubic feet of sediment. The material from the Ganges alone, if built up into a pyramid with a base of one square mile, would be 516 feet high. "But the Ganges is beaten by the Mississippi, for its pyramid would rise to 804 feet; while the Hoang-ho works yet harder to fill up the Yellow Sea, for the pyramid formed of its detritus would tower up to 2190 feet"—half as high as Ben Nevis.

If we assume that the average mineral contents of the rivers of the globe are 20 parts in 100,000, then each 5000 years the rivers will carry their own weight of solid matter to the sea; but of course rivers erode at different rates, and therefore lower their basins at different rates. With reference to this lowering, Sir Archibald Geikie gives the following interesting table.

Name of river	Area of basin in square miles	Annual discharge of sediment in cubic feet	Fraction of foot of rock by which the area of drainage is lowered in one year
Mississippi	1,147,000	7,468,694,400	$\frac{1}{6000}$
Ganges (Upper)	143,000	6,369,078,440	$\frac{1}{823}$
Hoang-ho	700,000	17,520,000,000?	$\frac{1}{1464}$
Rhône	25,000	600,381,800	$\frac{1}{1528}$
Danube	234,000	1,253,738,600	$\frac{1}{6846}$
Po	30,000	1,510,137,000	$\frac{1}{729}$

Otherwise expressed, the Mississippi erodes a foot in 6000 years, the upper Ganges erodes a foot in 823 years, the Hoang-ho a foot in 1464 years, and the Rhône, Danube,



AN UNDERGROUND RIVER IN THE MAMMOTH CAVE, KENTUCKY

and Po take 1528, 6846, and 729 years respectively to erode the same depth. At the rate of erosion of the Mississippi, North America would be worn down to sea-level in about four and a half million years; and at the rate of erosion of the Ganges, Asia would be reduced to sea-level in a little more than 930,000 years; while if Europe were eroded at the rate of the erosion of the Po, it would be washed away down to sea-level in less than half a million years.

Naturally, when rivers are in flood their erosive power is greatly increased, so that a swollen river may carry ten or twenty times its normal amount of mineral matter. In the Nile in May, 1875, there were 4772 parts of solid matter in every 100,000 parts of water, and some rivers in flood are like thick pea-soup. The destruction wrought by turgid rivers may be very great and very rapid, especially when the water bursts suddenly through dams and embankments.

We have already mentioned the devastation caused by the overflow of the Hoang-ho. The Indus has sometimes worked almost equal havoc. In June, 1841, it burst through a temporary natural dam; and Brown, in "The Earth and its Story," gives the following account of the ruin it wrought in its headlong career: "Houses and trees, men and women, horses and oxen, sheep and goats, were borne away at once, and all the alluvial flats in the bed of the river were destroyed in a moment, the flood passing Torbela, a distance of 550 miles, two days later, at the rate of 16·81 feet per second, or 11·4583 miles per hour. . . . Trees entirely disappeared from the Shayók Valley almost in an instant; and at Kulai, hundreds of miles lower down, about 500 of Rajah Golab Singh's army who were encamped in the bed of the Indus were swept to destruction. All the cultivated lands were swept away, and the once fertile Chach was sown with barren sands. . . . Opposite Attock, the waters of the Kabul River were checked and forced backwards for upwards of twenty miles by the mighty waves of the inundation, and the fort of Akora and the village of Messabanda were overthrown, while the back-wave of the flood was felt up the comparatively narrow valley of the Indus for ten miles above its junction with the Shayók. Lower down, the loss of property and life was not less than that described."


AN UNDERGROUND RIVER IN THE CHALK HILLS
Along this natural adit is flowing a stream that forms part of the Strood waterworks, the property of the city of Rochester.

When a mighty river like the Amazon or the Mississippi is in flood, it devours its banks by the mile. When the Amazon overflows, it becomes in parts a hundred or two hundred miles in width, and when it sinks and retreats to its original channel it undermines its sodden banks, so that they collapse into the water hundreds or thousands of yards at a time, carrying with them trees and animals. Great masses of trees get tangled together, and tumble about in the currents, "like marine monsters or drifting wrecks," while in some parts the river looks like broad meadows, from the accumulation on it of a green plant.

In the Mississippi, before man cabined and confined it between artificial embankments, floating rafts of trees were found on a colossal scale, and some of its tributaries were quite choked up with the flotsam and jetsam of forests. In many places a man might cross a great river on driftwood green with growing vegetation without knowing it. One great accumulation of trees on the Red River is known as the Great Raft, and for twenty-two years the Federal Government vainly laboured to remove it. It now covers the Red River for more than a hundred-miles. The Congo, the Orinoco, the Ganges, bear similar rafts, woven of trees and driftwood, and covered often with luxuriant living vegetation. Sometimes the rafts break away from their moorings and drift down the river like floating islands. They are sometimes seen fifty or a hundred miles out at sea off the mouth of the Ganges;

FROM RACING TORRENT TO STONY WASTE

THE COMPARATIVELY DRY COURSE OF THE SAN PEDRO RIVER IN SUMMER

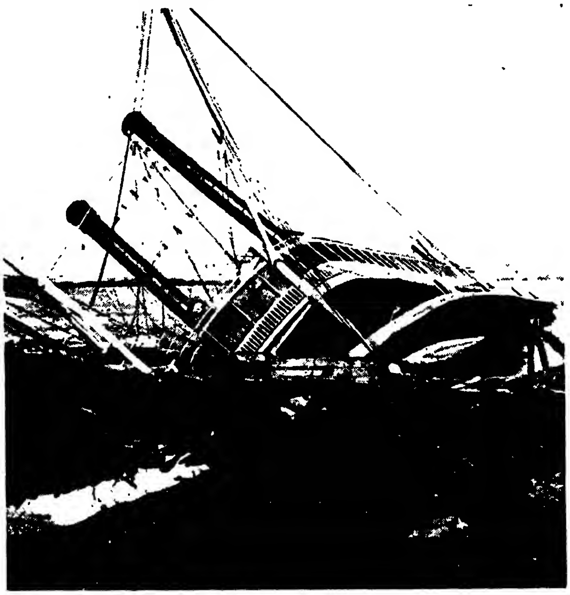
SAN PEDRO RIVER BREAKING DOWN CLIFFS

A DRY RIVER BED AT SONORA, MEXICO

THE SAN PEDRO RIVER IN FULL FLOOD DURING THE RAINY SEASON

and no doubt such rafts may float for long distances, and eventually carry animals and plants far from their native land.

Whether large or small, all rivers erode the land, and rapidly or gradually deepen their beds; and all over the world we find the excavations of rivers in the shape of glens and gorges, and ravines and barrancas, and cañons. Some of the most remarkable river-cuttings in the world are the cañons of Colorado. Here the River Colorado and its tributaries, as if with a colossal knife, have cut gashes thousands of feet deep in a vast high plateau which extends between the western side of the Rocky Mountains and the head of the Gulf of California. The Grand Cañon of the Colorado River is about three hundred miles in length, and ten miles in breadth, with almost perpendicular sides 4000 or 5000 feet high, and along the centre of the cañon is a gash, 1000 feet deep, in which the river flows. So numerous are these cañons, so steep their sides, that many rivers cannot be reached; and the only way to go comfortably across the country would be to use an aeroplane. If a hunter should shoot an animal, and the animal should fall from the plateau down one of these cañons, it would require almost a day's journey to retrieve the body.



A MISSISSIPPI STEAMER WRECKED BY STRIKING A SUBMERGED LOG, NEAR NEW ORLEANS

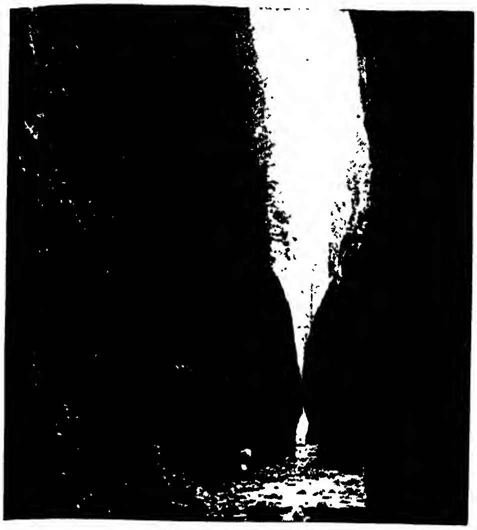
In the Himalayas, mountain torrents have cut such ravines in the mountain walls that they serve as gateways to admit the warm air from the south, and thus moderate the climate on the north side of the Himalayas.

How quickly it is possible for rivers to excavate is seen in the case of the River Timeto, which in less than a hundred years made a cutting 50 to 60 feet wide, and 40 to 50 feet deep, through a dam of lava thrown across its channel during an eruption of Mount Etna; and it is estimated that in eleven years the Niagara Falls wore away about ten million cubic feet of rock.

But rivers are not merely destructive: they are also constructive; they "draw down æonian hills," but they also "sow the dust of continents to be." Rivers do not retain for ever in their water the soil and rock they erode; they carry it for a certain distance and then precipitate it. Indeed, destruction and construction, erosion and precipitation, proceed *pari passu.* Always when the speed of any sediment-laden river slackens, a certain amount of the sediment is deposited. Thus at the point where mountain torrents reach the plain there is often a fan-shaped cone, with apex pointing up-hill. In the case of large streams, such as occur in the upper basin of the Indus and on the Rocky Mountains, the fans may be many miles in diameter, and some hundreds of feet deep. For like reasons there is usually a deposit of sediment in the concavities of the curves of winding rivers.

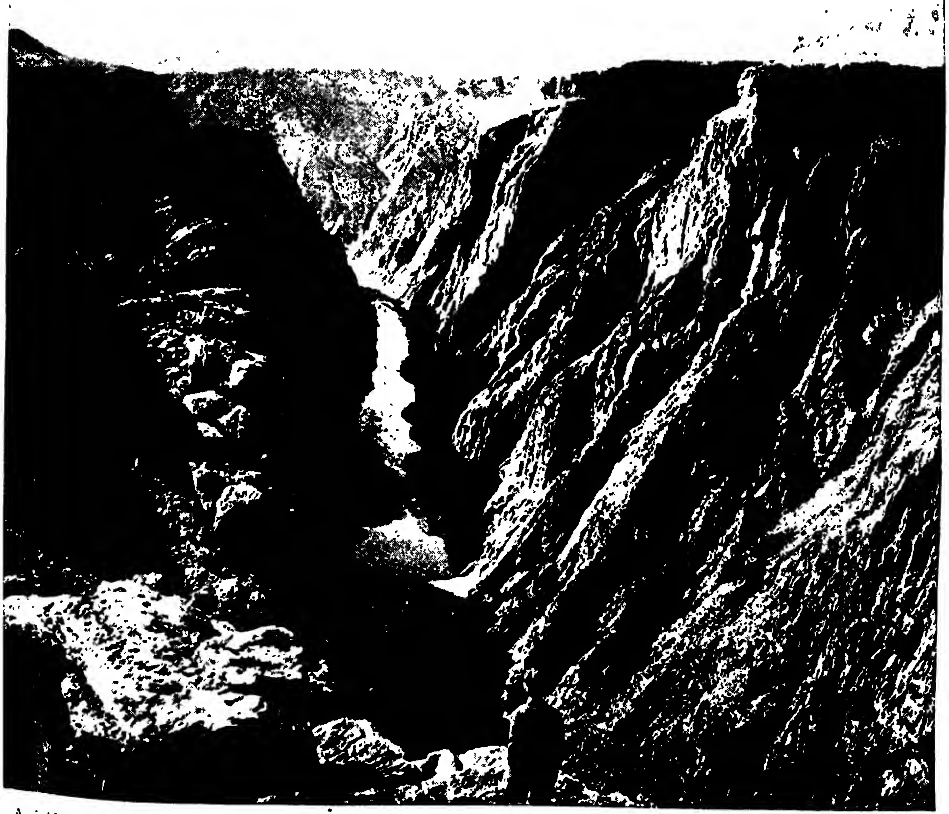
Again, when rivers overflow their banks the current is checked, and a great part of the sediment they carry is necessarily deposited. A flood deposit of this kind it is that deposits the rich alluvial mud of Egypt, on which the country's fertility and prosperity depend; and until the banking up of the Mississippi, continual overflows must have deposited an enormous amount of sediment on the surrounding country. For miles round Bâle are found pebble-beds deposited by the overflowing Rhine, and the frequent floods of the Po have covered the plains of Lombardy and Piedmont with gravel. In many cases raised terraces are found running parallel with river-beds, these terraces being the product of precipitation during floods. As the terraces are raised higher and higher by layers of sediment, and as the river-bed deepens, they become eventually above flood-level, and are left high and dry.

ROCKS SOFT TO WATER AND HARD TO AIR



ONEONTA GORGE, COLUMBIA RIVER, OREGON

GORGE IN THE GRAND CANYON, ARKANSAS



A VIEW OF THE GRANITE GORGE FROM THE PLATEAU BELOW BRIGHT ANGEL, ARIZONA

Sedimentation also occurs when a river flows into lakes, since the flow of the river is of course checked, with consequent deposition of sediment. Where the river enters the lake the deposit spreads out in a fan shape over the bottom of the lake where the river enters. By degrees the sediment deepens, and eventually part, or even the whole, of a lake may be filled up. The Lake of Geneva, through which the Rhône flows, must once have extended fourteen miles up the Rhône Valley to St. Maurice. In the time of the Romans, Port Valais was situated on the margin of the lake, but it is now two miles from the water's edge. When two streams flow into a lake, their sediment may be mutually deposited across the centre of the lake, and eventually divide it into two. Thus the Lake of Thun and the Lake of Brienz are now separated by an arm of low-lying land about two miles wide, on which Interlaken is built, but it is probable that the lakes were originally one, and that the arm of land was made from the deposit of the two rivers—the Lombach and the Lütschine—which now flow respectively into the Lake of Thun and the Lake of Brienz. To the shores of the Lake of Thun 203 acres have been added by deposit in 173 years; and in the same time the Aar has formed a delta in the Lake of Brienz nearly 4000 feet broad. In twenty-seven years the Reuss, flowing into the Lake of Lucerne, has deposited a delta of sediment estimated at 141,000,000 cubic feet; that is to say, it has deposited sediment at the rate of 19,350 cubic feet per day, which, again, is equivalent to a solid block 50 feet long, 43 feet wide, and 9 feet high.

Great as these alluvial deposits may seem, they do not equal in importance and extent the alluvia deposited in river estuaries. As rivers approach the sea, they flow more sluggishly, both because their bed is wider and because it is flatter, and thus at this time, and in this position, there is a special tendency to deposit sediment; and this tendency is increased by the fact that the salt water itself favours deposition. Sometimes the deposit takes the form of a bar or bank of gravel, sand, or mud across the mouth of the river. At the mouth of the Mississippi there is a bar "equal in bulk to a solid mass one mile square and 490 miles thick," and it advances at the rate of 338 feet each year.

Not bars and banks, however, but actual stretches of low land, are the characteristic sedimentary deposits at the mouths of rivers. The low land thus formed is usually called the *delta* of a river, a name first applied by the Greeks to the alluvial tract at the mouth of the Nile because of its supposed resemblance in shape to the Greek letter delta (Δ).

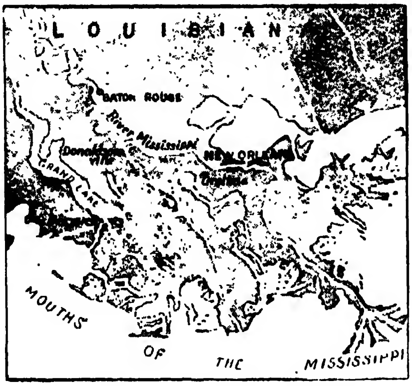
THE CAUSE OF THE RECESSION OF THE NIAGARA FALLS

When we examine these alluvial tracts laid down by rivers we are surprised at their extent. The so-called "Low Countries" are nothing more or less than the alluvial deposits of the Rhine, Meuse, Sambre, Scheldt, and a few other streams; and not without truth did Napoleon Buonaparte assert that the Netherlands were made of the mud of French rivers.

The Rhône, even though it drops so much sediment in Lake Geneva, has still succeeded in making a delta in the Mediterranean, and adds to it every year about four millions of cubic mètres of sediment. Since the Roman period it has formed from 77 to 116 square miles. The Po works even more vigorously, advancing its delta at the rate of 230 feet a year, so that Ravenna, originally on a lagoon, is now four miles inland, and the port Adria no less than fourteen miles from the Adriatic Sea, to which it gave its name. At parts the coastline has encroached no less than twenty miles on the sea, and in time its upper end will be filled up. On the other coast of Italy the Tuscan rivers are hard at work, and every year deposit twelve million cubic yards of sediment within the marshes of the Maremma. The Tiber adds about twelve feet a year to the coastline near Civita Vecchia; and the ancient harbour of Ostia, which was once at its mouth (hence the name of Os, a mouth), is

now three miles inland, and half buried in mud. The Danube also is busy delta-making; and during the last 1900 years its delta has advanced nine or ten miles into the Black Sea.

But these deltas are small compared with the deltas of the great rivers of the world. Take the delta of deltas, the alluvial deposit of the Nile. This delta is now 180 miles wide, and contains an area of nearly 9000 square miles. Memphis, which was once on the sea, is now 100 miles inland. All this land is a gift of the Nile; it has been made of its mud; and since almost all the mud comes down from the hills of Abyssinia, Egypt, geologically speaking, is an annex of Abyssinia. Yearly about 61,000,000 cubic metres of mud are debouched by the Nile. About two-fifths of this is added to the delta, while the rest is carried away by the sea, and eventually thrown down along the coast of the El Arich desert. The flooding of the river, of course, diverts much of the mud from the delta to Upper Egypt; and it has been calculated that the surface of Upper Egypt has been raised by sediment 6 feet 6 inches in the last 1900 years.

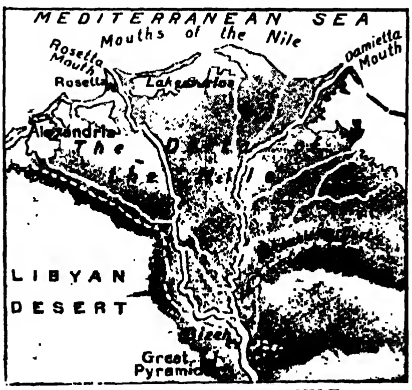


THE DELTA OF THE MISSISSIPPI

Larger still is the delta of the Hoang-ho, whose yellow mud has made a tract of alluvium extending over nearly 100,000 square miles, and constituting one of the most important provinces in China. Once the mountainous mass of Shantung stood isolated in the sea; now it is joined to the mainland by alluvium. So great is the discharge of sediment that it has been calculated that in sixty-six days there is enough deposit to form an isle one square mile in extent and 118 feet in height; and new islands are, indeed, being constantly formed. It is probable that the Yellow Sea will be quite filled up in about 50,000 years. How fast the sea is shoaling up is shown by the fact that the town of Pootai, which was about 600 yards from the sea in 220 B.C., was $43\frac{1}{2}$ miles from the sea in 1730; and that the town Seen-shway, which was on the sea-shore in 500 A.D., is now eighteen miles inland.

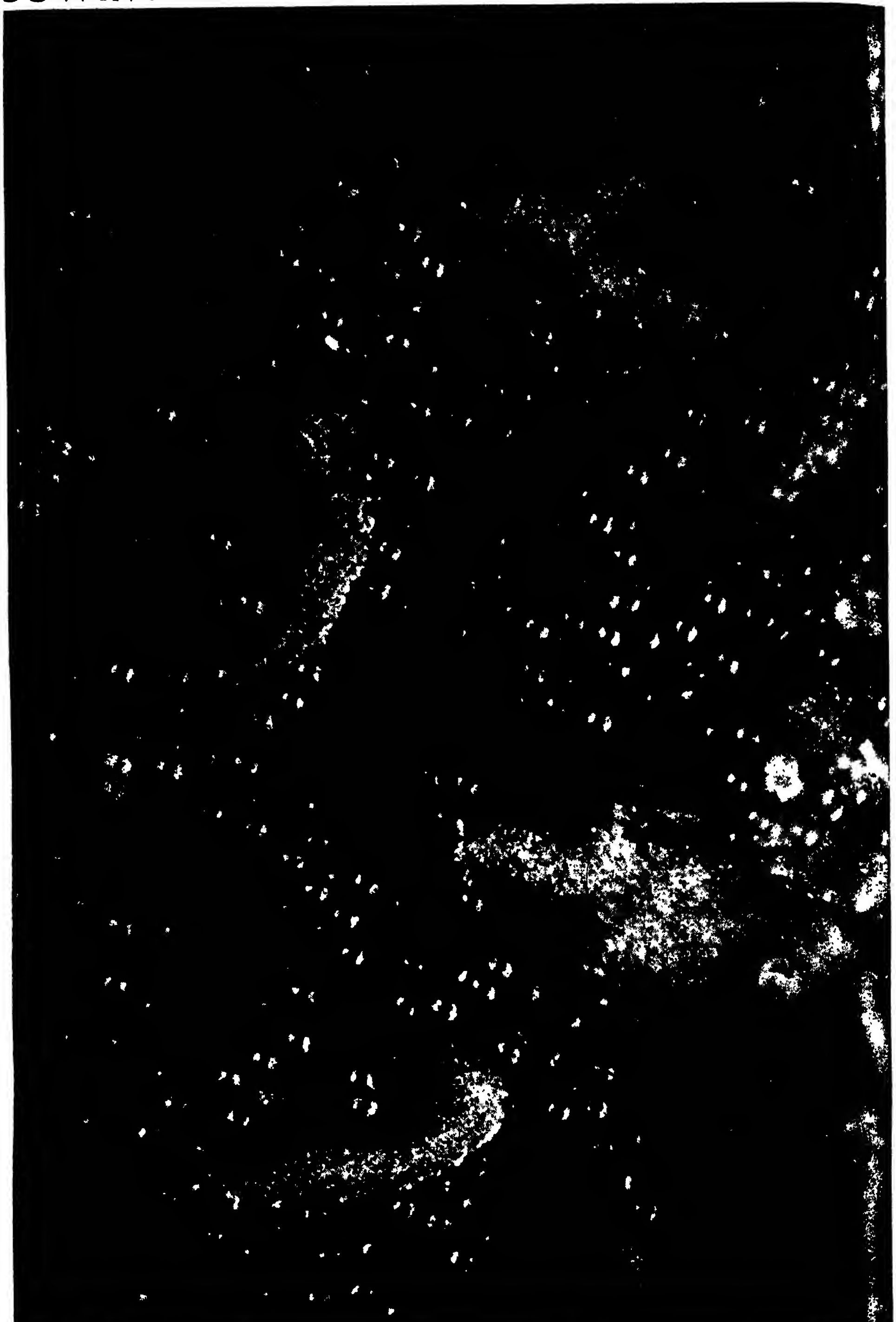
The combined delta of the Ganges and Brahmapootra covers between 50,000 and 60,000 square miles. It consists of sand, clay, pebbles, peat, and remains of trees, and it has been bored through to a depth of 481 feet. The delta would be much bigger were it not that about thirty-one miles from the mouth of the Ganges there is a deep submarine pit, known as the Great Swatch, into which much of the sediment sinks.

The Mississippi delta covers 12,300 square miles. It extends 220 miles into the Gulf of Mexico, and is advancing at the rate of 262 feet yearly. This, however, by no means represents the total deposit of the great river, which is not only building this delta above the waves, but is laying in the bottom the foundations of a far bigger delta. The total discharge of solids by the Mississippi has been calculated at 406,250,000 tons—enough to bury London and cover St. Paul's in the course of fourteen months. The delta of the Indus extends over an area of 3000 square miles. The delta of the Amazon is nearly 200 miles broad; and it would be much broader were it not that much of its mud is swept hundreds of miles out to sea.



THE DELTA OF THE NILE

When we consider all this constructive work done by rivers, we realise that they build up almost as quickly as they pull down; and when, later on, we come to deal with the origin of mountains, we shall see that the new mountains are largely due to the mud of the old ones, and that the action of the waters disintegrates the oldest and hardest layers of the earth's crust and scatters them over the globe, to be re-formed into rocks usable in man's industries.



In this highly magnified photograph ripe pollen-grains are to be seen falling from the stamens of a mallow flower—an enormous quantity of living matter produced in and by the germ-plasm. Each grain is a gamete, or germ-cell, conveying the male factors for reproduction to combine with those of the ovum-cell contained in the ovary. From a photograph by Mr. J. J. Ward

EXPERIMENTAL BIOLOGY

The Need for a Wider Scheme of Experiment in the Region of Physiological Chemistry

PIONEER WORK OF LOEB AND MACDOUGAL

We have already seen the startling results which followed the return of biology to experiment. Darwin's magnificent work arrested, fascinated, irritated his contemporaries and followers, and they all set to work, hammer and tongs, attacking each other, and arguing out the meaning and consequences of the Darwinian theory, its relation to Genesis, and so forth; and the actual gathering of new knowledge under exact conditions languished for decades. At last—but it was a long time, from 1859 to 1900—came the rediscovery of Mendelism, which started experiment again; and we have followed its results with some closeness up to the point which they have now attained.

All this experimental breeding, which yearly increases by leaps and bounds, and gains knowledge and power in all directions, is plainly entitled to the name of experimental biology. But there are other questions, open to experiment and of high importance, which experimental genetics has not touched at all, at any rate in this country, and which are even deeper in their probing of the mystery of life. Experimental breeding, as practised by the followers of Mendel and Bateson everywhere, and as practised by those two workers themselves, has strictly confined itself to limits which are really very narrow indeed, when looked at rightly, even though they permit of such great results. These inquiries, after all, do no more than concern themselves with the passage of certain "factors" from generation to generation, their couplings and repulsions and consequences. This is no small matter, if the "factors" in question determine the characters of living individuals in general, from the lowest bisexual forms—such as, say, the parasite of malaria—up to the highest, in whose blood that parasite conducts several of its genetic stages.

But it is evident, on consideration, that two very large problems are wholly untouched by all the foregoing work, colossal and fruitful though that be. One is the problem of the effect of altered conditions upon the development of living creatures; for let us not suppose that, because we have lately learnt so much about heredity or "nature," environment or "nurture" no longer remains. But, for some unknown reason, in this country we have no one who is working, in any important fashion, at the problem of what our American friends usually call experimental biology—the study of the action of, for instance, chemical agents upon development. Yet in America such students as Professor Jacques Loeb have attained great results, long discredited, but now accepted and recognised for more than a decade. The field is almost or wholly infinite, and practically untilled. That is one department of experimental biology to which we must devote some attention here —meanwhile trying to imagine how strangely our few words and meagre facts will read to the historian half a century hence, when the work started by Loeb has gone as far as, say, modern electricity from the researches of Faraday.

But there is a second field for experimental biology which is no less important. Its recognition and entrance are later in time than the work of Loeb, but earlier in order of logic, and we must begin with this question accordingly. It is the experimental study of the origin of variations. We remember that, for all its performance and incalculable promise, genetics as it is at present understood deals with the passage and combination and separation and distribution of "factors" the existence of which is already assumed. Sometimes a "variation" may arise because two of these factors have come into

novel association in a germ-cell or a zygote. But that tells us nothing as to the actual origin of new factors, though only by and in such origin has organic evolution occurred. The hope arises, therefore, that we may be able to learn something as to this truly fundamental question by means of experiment, which need not be particularly difficult of accomplishment.

Thus, we have the vegetable world at our disposal, with the "germ-plasm" of most plants easily accessible, the generations succeeding one another rapidly, compared even with our own brief lives, and no practical difficulties—as, for instance, the question of cruelty to animals—in our way. Yet here, again, for some unknown reason, we have done nothing at all on the necessary lines in this country, and must turn to the United States for the creation of a new development of experimental biology. What has been done, and remains to do, will be clear enough if we look afresh at the nature of the problem, and especially if we contrast the appearance it presented to Lamarck with that which it wears for us.

The Superseding of the Vague Ideas of Lamarck and Darwin

For the great pioneer of a century ago everything was necessarily vague. He believed that, somehow, circumstances act on the body of a parent in such wise that the offspring are other than they would have been, and that their other-ness may be novel and useful and progressive. There is no confusion in science like that which commonly prevails here; and the reader must observe that we are not mentioning that subordinate part of Lamarck's theories which is usually spoken of as the whole—namely, the supposed enlargement of a future son's biceps because his father is a blacksmith and enlarges *his* biceps. We here allude to the essential part of Lamarck's theory, which was that altered circumstances alter the structure of living things in correspondence to them—as, for instance, that the occurrence of light would incite the formation of eyes—and that these changes, so produced in the individual, were somehow inherited by its offspring.

But Lamarck could not possibly know anything of the exact physical and physiological relation of parents to offspring, as we know it now. For him, as for Darwin, with his theory of "pangenesis," the new creature sprang from the *whole* of the body of its parent, every part of which was somehow represented in the living material from which the new creature developed.

Darwin, as we remember, put forth what seems to us now to be the fantastic theory that all parts of the parental body gave off "gemmules" which gathered together to form the germ-cells. Now, if we are to attack the problem of the origin of variations, the actual genesis of the "factors" whose subsequent exodus Mendelism so sucessfully traces, we must begin by clearly seeing what the nature of the problem really is, and how immensely different from Darwin's idea of it. Once we have gone so far, we shall be in a position to make and to profit by experiments exactly designed to "touch the spot."

The Modern View that New Characters Come into Existence in the Germ-Cell

Everything turns upon the making of the germ-cells. The germ-cell, or gamete, contains its endowment of factors, and is what it is, and will be what it will be. It meets another such germ-cell, from an individual of the opposite sex, and that second germ-cell also has its factors. The new individual or zygote, formed by the yoking of these two, is primarily determined by, first, the factors these two germ-cells contain, and second, the way in which the two sets of factors react upon each other. Granted so much, we see that if the individual exhibits a new character, a true original variation, not a merely novel combination or separation of "factors," but something *more* than before, like the wings of a bird compared with a wingless reptile, or the brain of man compared with the brain of the ape, this new character came into being somehow *when the germ-cells which formed the new individual were made*, or, at the least, when one of them was made.

A Restatement of Weismann's Germ-Plasm Theory

The unexampled brain, the wonderful wings, or whatever the really new thing be, has its root-possibility in the germ-cells. Hence these germ-cells have the novelty in them, and *their making is actual evolution there occurring.* This has to be emphasised and stated in more phrases than one, because it is cardinal, and because all future advance of our knowledge must spring from the clear perception that original variation is something which happens when germ-cells are made.

We must remind ourselves, therefore, of the facts, so far as they have been outlined hitherto. Fortunately, we have a name for the making of germ-cells, and it is well that we should give this name a very special place in our minds owing to the unique importance of what it stands for. The

making of germ-cells, or genesis of gametes, is now known as gametogenesis. It occurs only in the pre-appointed tissue, to which Weismann gave the general, all but "mystical," name of the germ-plasm. It occurs alike in both sexes, any differences being relatively unimportant. Its continuance characterises what we call the reproductive period in the life of any individual, for it alone makes reproduction possible. The length of this period varies very widely in different species. It may be only a few hours in some insects or in some plants; it may be a period of many decades in some long-lived mammals, such as the elephant or man, or in some reptiles. In many species the period may be more prolonged in one sex than in the other. In all it coincides with the occurrence of gametogenesis; it is the period during which the gametes are being formed. True, they are not being formed from the body of the individual at large, as Darwin supposed; and we owe much to Weismann for teaching us, by his theory of the germ-plasm, that the gametes are formed from a special, separate, predestined tissue which is in a subtle but very real kind of sense in the parental body, but not of it.

Important Limitations of the Theory of Weismann

This true and valuable idea of Weismann unfortunately succeeded in misleading many of us, for many years, into the idea that the actual germ-cells already exist, preformed, in the body of a young individual, and simply leave that body at intervals during its maturity, as we see the pollen grains being shed from a flower, to choose a typical instance. The precise character of the facts has been widely overlooked by commentators and critics, though it need hardly be said that there is not a line in Weismann's treatise to excuse them. The facts are, first, that the young individual does bear within itself a special portion, "the germ-plasm," of which it is the host, and which has a special origin and an utterly different destiny, for it may live on in the bodies of all to come, while the individual body which carries it will soon die: and for clearly demonstrating this we shall ever be grateful to Weismann. But it is also true, has been known for decades, and can be observed under the microscope in myriads of instances at a few minutes' notice, that notwithstanding this "continuity of the germ-plasm," the actual gametes or germ-cells are formed during part (the reproductive period) of the life of the individual, from the germ-plasm, which is neverthless itself of such vast antiquity, and which, as a whole, was not exactly made *from* the individual body.

We begin to see what must be the meaning of this fact, that though the living material which is the source of the germ-cells is not made by the individual, nor during the life of the individual, yet the actual germ-cells are so made. Consider the immense contrast between the actual case, and what is too often supposed to be the case, from the standpoint of what it makes possible.

The Germ-Plasm Like Bullion, that may be Minted Individually

The current misunderstanding of Weismannism is that the individual is born with, so to say, a number of definitely minted coins in a special pocket, and that the reproductive period is simply that during which these coins may be spent. Nothing of the kind happens. The fact is that (if we continue the image of the coins) the individual is endowed, even at birth, or what corresponds to birth, with a special collection or quantity of something more like bullion, peculiar material, of peculiar origin and destiny, meant for the construction of very definitely minted coins, each a little different from any of the others, but none of them minted as yet. These coins, the germ-cells, are minted during the reproductive period, and the process of mintage is called gametogenesis.

Now observe how extremely limited, on the view that the coins are already minted from the first, is the possibility that the life of the individual who bears them can affect them in any direction. It was thus—because this was the popular idea of Weismannism, and one shared by many biologists who let other people do their reading for them—that arose the notion of the germ-cells as living in a world apart, where nothing that happened in *our* world could touch them.

The Effects of Nurture Upon Individual Development

On this view, long declared to be the last word of wisdom on the subject of organic evolution, it was declared that the germ-cells were inviolate, utterly immune to all external influences (this being what the "non-transmission of acquired characters," like the blacksmith's biceps, was supposed to mean); and it amounted to this in the teaching of the so-called Weismannians: that evolution could never occur, variations were impossible, for no cause of variations existed. The germ-cells were shut up, like coins in a locked safe, until the time for them to be used. The logical necessity

from this egregious argument was that evolution could never occur or have occurred, for all possibility of variation was excluded.

But it has been known for decades, long before Weismann wrote at all, that this picture of the germ-cells is utterly unlike the facts. What is called the "maturation of the ovum," the extraordinary series of processes at the end of which, and only at the end of which, we find what was then called a "ripe ovum," has been familiar for a long time: and here was demonstrably an active, living process, which meant and involved an exceptional supply of blood for nourishment and oxygen, which occurred during and characterised the reproductive period of the life of the individual, and without which an effective ovum, or female gamete, as we now call it, could not be found. That fact alone was sufficient to show that what happens during the life of the individual is not entirely to be ignored—even if babies are not born with a good French accent because their parents lived in Paris. And the difference between those days and these lies in the fact that the "maturation of the ovum" is now known to be a particular case of gametogenesis, and to have an exact parallel in the case of male gametes as well.

Life Mintage in the Germ can be Modified by Parental Surroundings

Now for our theory of organic evolution—and for the very possibility of organic evolution, the importance of the occurrence of gametogenesis as a process dependent upon the life, the health, the blood, or other nutrient fluid of the individual in whose body it occurs, cannot be overstated. As we saw when we referred to the suggestions made by Professor J. T. Cunningham, our recognition of gametogenesis as a vital process dependent upon the vital activities of the individual in whom it occurs clearly opens up the possibility that those vital activities may affect gametogenesis, and therefore the characteristics of the gametes in which that process results. In other words, we find ourselves compelled to make a fresh start, and study from the beginning the influence of the parental body upon the details of gametogenesis. This may mean the discovery of the cause of variations, and therefore of organic evolution; it directs us to the real "origin of species," which Darwin did not discuss. Everything, in short, which Weismann's influence led most of us to regard as a *chose jugée*, a matter which had been adjudged and disposed of, on the ground that the germ-cells were minted coins from the first, must now be studied from the beginning. The mintage, we see, occurs during the reproductive life of the future parent, and is modifiable thereby to an extent of which at present we know substantially nothing.

The Need for a Study of the Effects of External Conditions

Here, most evidently, is an infinite field for experimental biology. In a word, we must take individuals, as, for instance, plants, the character of whose offspring we can certainly predict (if we take several individuals and repeat our experiments); and then we must modify those individuals in ways which, we are sure, must touch the "germ-plasm," and must see whether they now bear offspring of another kind. If the offspring are different, we can be sure that we have somehow modified the process of gametogenesis in the parent individuals, so that it results in gametes which are not what they would have been without our interference. This is a department of the study of life which, we now begin to see, transcends in importance anything that even the Mendelians have demonstrated hitherto. Not that they are to be blamed—except in so far as they have their share of responsibility for the general neglect in this country of the work done by the American botanists. The Mendelians have their own initial task before them; and it is clear that, until they have found out what normally occurs in heredity, we cannot usefully make any experiments as to the effects of altered conditions of parental nurture.

The Problem of External Influence One of Physiological Chemistry

It has been made evident by the Mendelian work that to ascertain the normal facts under constant external conditions is the first necessity. And as for a certain amount of experimental work upon the influence of varied parental nurture, done in the nineteenth century, before Mendel's work was known, all that must now be repeated, simply because it is only now that we begin to know what to expect *before* we vary the conditions.

The problem is essentially one in what is called physiological chemistry. We think of it no longer as either Lamarck or Darwin did; we think of it not in terms of the action of external conditions upon the parental body as a whole, but in terms of the action upon the "germ-plasm" of *its* environment. Now, the environment of the germ-plasm is the body which bears it, and the details of this environment vary widely

in different cases. If, for instance, we consider the germ-plasm of a flowering plant, and that of any o fthe higher animals which correspond in the animal world to the flowering plants in the vegetable world, we see notable resemblances and also notable differences. The germ-plasm of the plant, as we see it, or imagine it, giving rise to the male and female gametes, the pollen cells and ova, is by no means free from something very like the *immediate* action of the environment. We are now acquainted with many of the properties of light and ethereal radiations, and we have been taught how potently the electrical state of the atmosphere may affect the growth of plants. Knowing as we do how many of these rays can penetrate matter to a considerable degree, we see that the germ-plasm of a flower, in which the process of gametogenesis is occurring, can no longer be regarded as something utterly withdrawn, free from any possibility of modification by the direct action of the external world.

The Study of Radio-Activity on Germ-Plasm in Plant Life

What this direct action can affect remains to be seen. Nothing along the lines here hinted at has yet been done, in America or elsewhere. Yet the action of radio-activity and of the Röntgen rays upon dividing cells is known to be immense, as the medical study of their action upon cancer-cells has proved; and in many instances the whole type of the cells under their influence can be altered, as when prolonged exposure to the Röntgen rays produces a terrible change in the nuclear division of normal skin-cells, and so forms malignant growth, which is, in a very true sense, a *variation* in the cell-type of the part affected. When these facts are remembered, we see that the study of the action of ether-waves upon the germ-plasm of those forms of life in which, as in most plants, the germ-plasm is almost freely exposed may yield results of unlimited importance.

Now, in the corresponding forms of animal life we notice a great difference. In them, as a rule, the germinal tissues are deeply placed in the substance of the body. The ovary of the flowering plant, and the ovary of any vertebrate, may be conveniently compared and contrasted in this respect, and at once we see that the vegetable ovary is almost unreservedly exposed to the direct action of external influences, from which the animal ovary is wholly withdrawn. Probably no form of natural radiation can ever penetrate the animal body so as to reach the ovary and affect the processes of gametogenesis occurring within it. This withdrawal of the germ-plasm, in so many animals, as if no outside fact could affect it, has misled many writers into the supposition that the animal germ-plasm, at any rate, is usually to be reckoned as proceeding on its appointed vital course without any relation to the rest of the Universe at all.

Other Life Equally Responsive to Influences of Environment

How absurd that assumption was, we see when we observe the respect in which the germ-plasm of a rose and of a rabbit, so differently placed in relation to the direct action of the environment, are similarly placed in relation to the body in which the germ-plasm is housed. In both cases it is clear that the life of the germ-plasm depends upon the life of the individual to whom it belongs, or who belongs to it, as Weismann would prefer us to say. Gametogenesis is the essential expression of the life of the germ-plasm. It consists of cell-formation, the cells formed being discharged in various ways when the proper time comes. If we weigh the germ-cells that leave, for instance, the head of a dandelion, or estimate the weight of the germ-cells produced during the reproductive period of any of the higher animals or plants, we see at once that a relatively enormous quantity of living matter is produced in and by the cells of the reproductive tissues—in and by the germ-plasm.

The Effect on Gametogenesis of the Nutritive State of the Individual

This means necessarily that material of various kinds, albumins and salts and water and sugar and fat, have been supplied to the germ-plasm by the blood and lymph, in the case of an animal, and corresponding substances in the nutritive fluids of a plant; and in each case the vital activity of the germ-plasm has formed, by the process called gametogenesis, the "ripe," mature, or final gametes which primarily determine the characteristics of the next generation. There can be no criticism of the assertion that the process of gametogenesis must therefore in part depend upon the nutritive material which is supplied to the germ-plasm during its occurrence.

This has been clear enough in a limited range of instances, wholly morbid and exceptional—namely, the action of such substances as alcohol, to which the name of racial poisons has been given. All that question has its own importance, from

some practical points of view, and it is further important as leading to the demonstration that the nutritive state of the individual may affect the gametogenesis occurring in that individual. But the effects here are for the worse; they are degenerative, and, if long continued, lead to the extinction of the species. Nothing of that is of any service to our problem, which is to explain not the destruction or degradation of high forms of life already evolved, but the upward process by which their evolution occurred. We want to know whether the modification of the nutritive fluids of the parent may ever cause true, healthy, original variations in the offspring. After many decades of argument, the business of putting this fundamental question to the test of experiment has been begun in America. In a presidential address to a section of the British Association two or three years ago, Professor Gilbert Bourne drew attention to the American work, and remarked upon our neglect of it in this country; and the present writer has been calling attention to the subject since 1908.

The Development in America of New Forms of Offspring by Chemical Experiments

Professor Macdougal, of New York, has definitely succeeded in modifying gametogenesis in plants, so that the gametes were other than they would have been, and thus the offspring developed from those gametes exhibited true, original variation. An essential distinction between this demonstration of Macdougal's, and the work done on the Continent upon the action of alcohol upon gametogenesis, is that the new forms of plants produced by Macdougal were not morbid, not simply vitiated versions of their parents, but were types really new in certain details of their structure. They were demonstrably produced as a direct result of the introduction, by injection or otherwise, of certain unusual salts into the parent plants—the novel agent being, in some instances, introduced directly into the ovaries of the plants, so that the chemical environment in which gametogenesis was there occurring was modified. Needless to say, many substances might be thus introduced which would kill the plant altogether, and many others which would result in the production of feeble, deformed, or defective offspring. That is only too easy, and it has a bearing upon a department of eugenics. But destruction is always an easier feat than creation—any housemaid could light the fire with the manuscript of "The French Revolution," but only Carlyle could write it. Similarly, anyone can alter the life of a living thing, or of its offspring, in the direction of death and destruction. But Macdougal introduced salts which were not very different from those normal to the plant—at least in some instances—and he obtained forms of offspring which were genuinely new.

New Forms of Cultivated Life that Breed True and Are Inherited

An evident test is required before we could say that the new forms, shown in the offspring, were of the character of genuine variations, due to the formation of a new type of germ-plasm and gametes. That is the test of breeding, in their turn, from the new forms thus produced. In several experiments Macdougal was able to show that the new forms bred true, so that new species had definitely been formed by the action of altered chemical conditions upon gametogenesis. More remarkable still, in some instances Macdougal found that the new forms were inherited by successive generations according to Mendel's law, showing beyond a doubt that his alteration of the nutritive state of the original plants had really effected a change in the "factors" of the gametes produced in them. Certainly the time has come when this work must be repeated and extended in this and other countries. Too much must not, however, be asserted for what has already been done. The new forms made by Macdougal could in no instance be called progressive or constructive, in the sense in which the evolution of higher from lower forms of life is progressive.

The Need for Study Whether Life is Formed Wholly from Within

It may well be that nothing other than a Bergsonian or vitalistic conception of life will ever give us the key to its sheerly creative deeds. But no acceptance of that view of creative evolution as proceeding from within Life, and not stamped upon it from without, will excuse us for neglecting to study, as far as possible, all the ways in which alteration of circumstances, environment or nurture, alters the forms assumed by living things.

It may be that our statement of the facts should be in other terms. Perhaps we should regard the new types as adaptations to new conditions of environment, rather than as mechanical results of the new conditions. But in any case we must extend these experiments without limit, for no man can say to what they may not lead.

Here we leave them, but not without once more reminding the reader that this origin of new forms by alteration of parental nurture is wholly distinct from any of the feats of Mr. Luther Burbank in America, or of Professor Biffen in Cambridge. These workers have done amazing things by experimental breeding, and have made new living forms of great value and unquestioned novelty, but there the secret has lain in the novel combination of elements or factors or characters already existing. Genetics teaches us that the individual is a living mosaic, and has now begun to make new designs by new combinations of the pieces of mosaic. But the deeper question and problem, which genetics does not touch, is as to where those pieces of mosaic, which it juggles with, came from, and how. From this point of view, the experimental production of a comparatively trifling variation that is really original is of more importance than Professor Biffen's creation of a valuable and novel wheat by the combination of factors which already existed, but were never in combination before.

A JELLY-FISH BEARING RIPE OVA WITHIN ITS BODY

Lastly, we note that experimental biology must study the effect of varied conditions upon the development of the individual or zygote, from its first formation onwards. It is a hard enough task to ascertain the facts of normal development—by which, after all, we only mean development under certain conditions which we regard as usual. But we must also study the facts of abnormal development—by which we may perhaps only mean development under conditions which we do not regard as usual. Here the field for study is infinitely large. Professor Loeb has made a beginning, and many other workers, notably in France, such as Délage, and in Germany, are at work here also. Already the evidence is conclusive that enormous effects, of the most unforeseeable and often bizarre kinds, may and do result from varied conditions of nurture which may appear to be of the slightest and most unimportant kind. Here also, as in the case which we have just been studying, destruction, deformation, vitiation, are easy to produce, and their degree is limited only by death, but it is a very different matter to produce changes of a positive or creative kind by means of any modification of the conditions of nurture during development. Destruction is easy, but construction seems well-nigh impossible.

On all this, where we are mere beginners, the future will pronounce. In the foregoing we have gone as far as our knowledge will at present permit towards elucidating the causes and conditions which determine the characteristics of individual organisms. Now we must pass on to study the great problems which depend on the fact that living individuals, however they come to be what they are, exist in vast numbers and in many different forms, and enter into many relations to one another, of mutual aid, parasitism, competition, and so forth.

All these relations have doubtless been much over-estimated, so far as their importance for the problem of organic evolution is concerned. For instance, we no longer entertain the strange delusion that the competitive and mutual destruction of species effects the "origin of species"; but these many and con trasted relations between living creatures, animal and vegetable, high and low, visible and invisible, are evidently responsible for many of the facts of the living world at any given time, and are therefore worthy of the closest study at all times.

A PLANT THAT BREAKS ALL THE RULES

This orchid (*Cattleya citrina*), from Mexico, reverses nearly all the normal conditions that govern plant growth. It flourishes [illegible] piece of dry bark, with its roots in the air, instead of in the soil. The atmosphere provides it with sufficient moisture, combined [illegible] that stored in its bulbs. It grows upside down, with its leaves towards the ground, and flowers in that position, as the photog[illegible] shows. Probably this characteristic is to throw off the excessive water of torrential rains, which afterwards rises from the gr[illegible] as aqueous vapour and supplies the plant's greatest need.

INTELLIGENCE IN PLANTS

The Movements of Roots, Leaves, and Other Organs; Sensitive Plants, and Response to Sunlight

PLANTS THAT CATCH AND EAT INSECTS

We are accustomed to associate the idea of intelligence with such animals as have a somewhat highly developed brain, but it is an extremely difficult matter to lay down any line of distinction to indicate where intelligence first makes its appearance. Looking at the idea of intelligence in the widest possible manner, and understanding that term as meaning purposive action, the doing of something for a particular end in view, we should be ready to admit that many of the processes going on in the leaves of plants can only be described as intelligent.

It was in that sense that Darwin compared the tip of the root to the brain of the lower animals. He said it was hardly an exaggeration to say that the tip of the root, thus endowed, "having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals, the brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements."

In this sense, plants have well-defined intelligence, which manifests itself in a thousand ways, particularly in the movements which their various parts display, either in search of food or for some other vital purpose. In this chapter we shall study in detail some of the more striking of these movements.

We may first notice the fact that the growth of a plant is not equal in all of its parts. Some portions exhibit a much more rapid growth than others, or grow during a longer period of time; and one of the results of this inequality of growth in different tissues is to produce movements in the various parts which are sometimes described as spontaneous. In both stems and roots the growth is usually more rapid on one side than on the other, and this results in the production of curvatures, or bends, unless the variation is such that the extra growth produced on one side is at once compensated for by a corresponding growth on the other. That is what actually happens at the tip of the root; and it has the result of making the root describe a spiral course through the soil, instead of a directly downward one. As a matter of fact, most stems in their upward growth also have a similar spiral movement, commonly in the opposite direction to the hands of a watch. The movement itself is termed "nutation."

If these spontaneous movements, of roots especially, be carefully studied, the observer cannot help being impressed with the idea that they have a very definite object in view. Hence the justification for the use of the expression "the intelligence of plants." Obviously, the end and object of the movements is to attain that position in the soil which is best suited for the furnishing of the nourishment required. This is seen even in parasitic growths, which direct their growing tips towards the axis of the branch on which they are growing, just as an ordinary plant directs its main root, in the first place, towards the centre of the earth, even though it adopts a spiral course to attain that direction. Seeds which lie under water sometimes send roots directly upwards. In all these cases the primary direction of the root-growth—the movement of the root-tip, that is—is extremely definite.

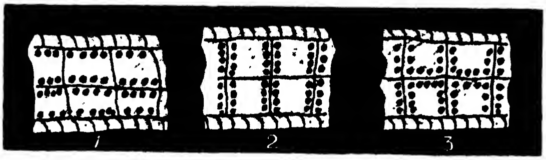
The directions taken by the secondary roots, however, from whichever part of the plant they may arise, are not so definitely circumscribed, though here, too, it is obvious that the movements are directed to reaching such positions as will give either security of attachment or moisture for nourishment. Study of all these movements shows that both those which take place in the aerial structures,

and those which take place in the root, follow the same guiding principle, though the latter, of course, are made much more restricted, from the nature of their environment. If the root were to grow straight down, it would not come in contact with nearly so much material as it does by following a spiral course. This latter evidently offers the best means of encountering the most desirable food-supplies. This is part of what is meant by the intelligence of plants.

Further, one may readily observe that the growing portions of roots invariably turn aside from dry or barren soils in favour of a part in which there is more moisture and more nourishment. This movement towards the moisture is called hydrotropism. In any considerable section of soil which has much vegetation growing at its surface, these movements of roots, in response to their environment, form an obvious and interesting study. One can see in any such cutting of ground a root turning away from dry, sandy, or inhospitable soil, until it comes to a richer deposit; and here, not having any necessity to turn further, it will grow now straight downwards through good material (see page 545). Arrived at the further boundary of this deposit, it will once more change its direction, and may even bend round and round, so as to keep in such a desirable neighbourhood.


SPIRAL ROOT OF EUPHRASIA

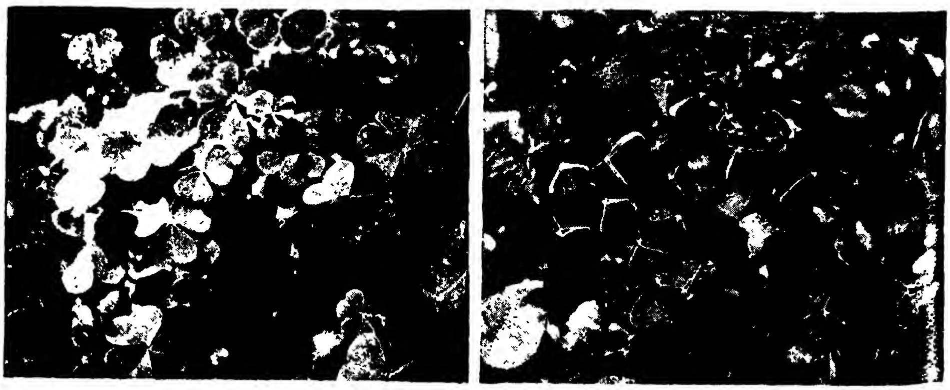
Perhaps one of the most interesting of all the many examples of the intelligence of plants, in reference to the movements of their parts, is to be found in connection with the attitude and arrangements of their chlorophyll granules in relation to sunlight. These granules, it must be remembered, float freely within the protoplasm, which can move them to different places. This permits of their being either equally distributed throughout the cell, or aggregated together in clumps, or otherwise arranged. Perhaps the best example of these movements can be seen in plants like the liverworts, or in the mosses, where the green of the leaf is noticed to be lighter or darker, according to the intensity of the light which falls upon it. The same thing takes place in many flowering plants. The darker tint is observed when the light is weakest, whereas, under the action of the most intense, direct sunlight, the leaf appears yellowish. These alterations in colour-appearance are due to actual movements of the chlorophyll granules, which take up different positions as the light varies.



THE MOVEMENT OF CHLOROPHYLL GRANULES IN A LEAF

This diagram of part of a section of a green leaf represents roughly the change in the movements of the chlorophyll granules in response to the stimulus of (1) darkness, (2) direct sunlight, and (3) diffused light.

A very simple experiment may be


WOOD-SORREL WITH LEAVES OPEN BY DAY BUT CLOSED BY NIGHT

A SENSITIVE PLANT, MIMOSA JUDICA, BEFORE AND AFTER HAVING BEEN BREATHED UPON

performed by anyone in this connection. If a piece of black paper be taken and placed on a leaf which is exposed to the sun, in such a way as to cover up a part of the leaf, after a time it is observed, on removing the strip of paper, that the portion of leaf underneath is dark green, in comparison with that which was left exposed and unprotected. That is light green.

A reference to a simple diagram in this chapter will explain this. We find that when the light is diffuse (3, page 2604), the chlorophyll granules so arrange themselves as to cover those walls of the cells on which the light falls perpendicularly. This gives such portions of the leaf a dark-green appearance. When such a cell becomes exposed to direct sunlight, the granules leave these walls parallel to the upper surface of the leaf, and accumulate on those which are parallel to the direction of the light (2). The tissue, as the result, assumes a much paler colour.

We have already, in previous chapters, referred to the movements of cotyledons, and what was then said should be read also in connection with our present topic. A word or two may be added, however, to the remarks already made in connection with leaves, concerning the movements of *compound* leaves, which exhibit interesting changes of attitude in such places where they are exposed to considerable cooling during the night temperatures.

DEVELOPMENT OF A WINDOW-PLANT ON THE SIDE TOWARDS THE LIGHT

During the ordinary hours of sunshine such leaves are placed more or less parallel to the surface of the ground, with the upper surface open to the sky, and thus catching the direct rays of the sun. It is obvious that if the leaf were to remain in this attitude during the hours of the night, there would be great loss of heat, on account of radiation towards the upper air. The intelligence of the plant, as we have agreed to understand that term, here shows itself by the leaflets which compose the compound leaf folding themselves together either upwards or downwards, according to the species concerned, so that their broad aspect is placed vertically. In this manner there is much less loss from radiation than there would otherwise be.

PINE-CONE DEVELOPED ON ONE SIDE

We may now turn our attention to an entirely different class of plant movement, namely, that which is associated with climbing plants, of which there are a large number whose stems are not sufficiently woody in texture to maintain a vertical or erect attitude. In a plant which has such a nature, one of two things may happen: the stem of the plant may continue to grow along the surface of the ground, bending or arching, perhaps, as it does so, but coming in contact with the soil at intervals. Such

plants have what are termed prostrate stems. On the other hand, however, there are a number of species which, in their efforts to reach the erect attitude, have developed various structures—some already considered—which enable them to grasp any neighbouring object that may afford a means of support, and to this object the plant attaches itself.

Our illustrations show examples of such plants in the tendrils of the bryony, in the coiling petiole of the common tropæolum and wild clematis, both of which are supported by their leaves. The peas and the vetches also exhibit their climbing movements in virtue of the modifications by which their leaves pass into the very thin threads, or tendrils, that wind so readily round any object sufficiently near (see page 2252). Another good example is that of the hop, but in this case the whole plant participates in the movement, the entire stem twisting to the right. These various examples may be seen in our illustrations.

LYSIMACHIA, A PROSTRATE-GROWING PLANT

Next we may turn our attention to an entirely different aspect of what we have referred to as plant intelligence. In a previous paragraph we made some reference to movements which take place in plants during the hours of night, to which the name of "sleep movements" has been given; and it will be remembered that these consisted in the adoption of certain attitudes of the leaves or leaflets. A somewhat similar phenomenon is to be noted in connection with some plants that exhibit these sleep movements, and also in others that do not. We refer to plants known by the general name of sensitive plants, from their different manifestations of this sensitive phenomenon. A number of the plants which assume the sleep position in the night exhibit a similar movement when they are either shaken or merely lightly touched, and, as a matter of fact, they appear to be even more sensitive to this disturbance than to darkness. The onset of a very slight breeze of air may be sufficient to cause the leaflets to fold up. In one well-known plant which grows in India (Oxalis sensitiva), so delicate is the apparatus concerned that even the slight disturbance caused by anyone walking in the immediate neighbourhood is enough to produce folding in the leaflets; and they open once more when the person moves away. Probably it was this phenomenon of the shrinking, as it were, of the leaves of certain plants at the approach of men that was responsible for their first being named "sensitive plants."

Although this curious change occurs in some of the same plants that adopt the sleep position at night, it is not to be therefore inferred that the two things are the same. The attitude of the leaf is determined by the condition of a little cushion of tissue, called the *pulvinus*. This cushion remains quite rigid in the sleep position, whilst on the other hand, it undergoes a very remarkable change in the movements produced by shaking the plant. It becomes less turgid, by discharging some of its water into another part, and the result of this is to cause a bending of the leaflet.

Under natural conditions practically the only two things which stimulate the protoplasm to act in this way are the action of the wind, and, still more emphatically, perhaps, the irritation caused by the falling of drops of rain on to the leaf. In the Indian plant already referred to, most remarkable movements immediately follow a shower of rain. The leaves which first come in contact with the drops fold together downwards, but not only do these leaves do so, but actually, also, those in closest proximity to them, even though no actual drops fall thereon. Well might such a plant be termed "sensitive." Even the leaf-stalk, which bears the mass of leaves, bends in the direction of the earth;

FOUR EXAMPLES OF CLIMBING PLANTS

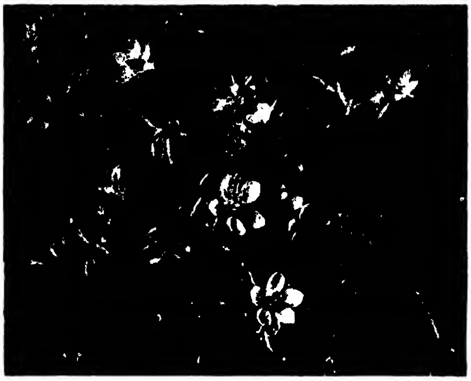
WILD CLEMATIS

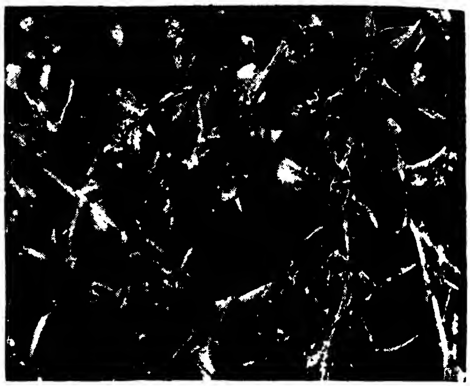
THE TWISTING STEM OF THE HOP

THE COMMON TROPÆOLUM

BLACK BRYONY

and the practical consequence of these movements is that the drops of rain-water flow over the bent stalk, and over the hanging leaves, so that all the moisture is immediately drained off, and none remains upon the surface. No better example can be imagined illustrative of plant intelligence, or movements directed by some principle towards the attainment of a definite purpose.



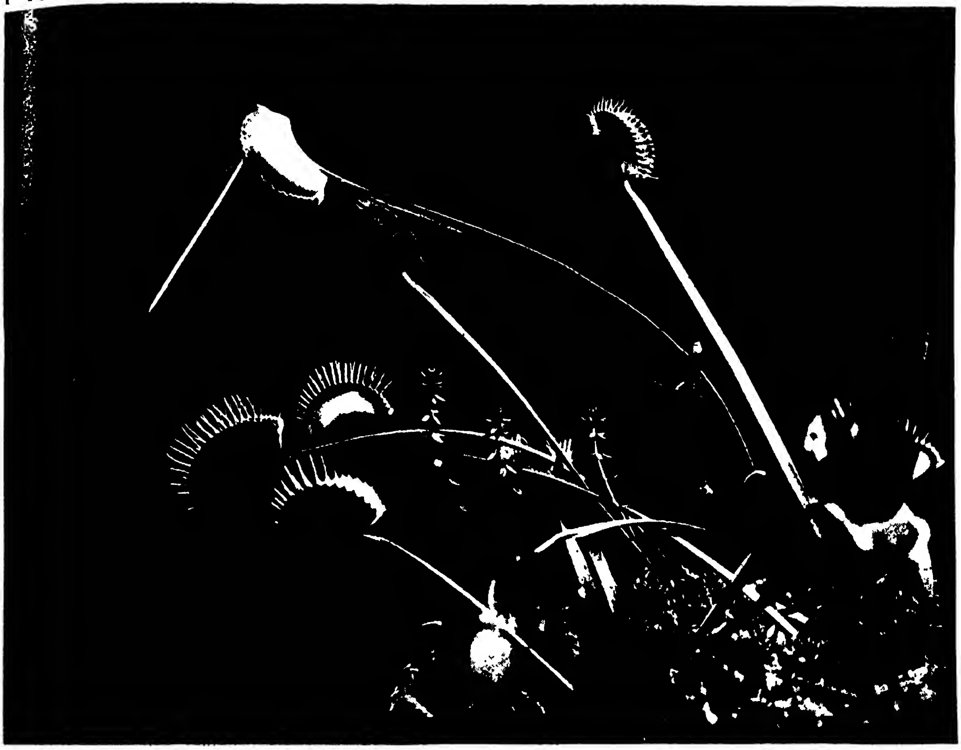


THE FLOWERS OF SAND-SPURREY, FULLY EXPANDED IN SUNLIGHT BUT CLOSED DURING RAIN

Very similar processes are seen in the leaves of the sundew, and in those of Venus's fly-trap, as well as in some of the mimosas. The actual movements are not identical in all these cases, but they are produced by the same sort of influences, and for precisely analogous purposes. The freeing of the plant from rain-drops, however, though obviously one of the objects in these movements, is not the only one. This may be concluded from the fact that quite other conditions than rain produce the same movements, particularly such factors as hot, dry winds, impregnated with particles of dust or sand. Here it is obviously to prevent excessive transpiration that the leaves fold together. So we may safely conclude that several different advantages accrue to the plant in virtue of the powers of movement we have been describing. At night the loss of heat by radiation is minimised. In the heat of the day extreme transpiration is kept in check. In wet weather, injury to the leaves, or possibly to the whole plant, which might collapse under the weight of accumulated water is prevented.

THE CEREIES, THAT BLOOM ONLY BY NIGHT

FLOWERS OF THE COMMON DAISY, CLOSED AT NIGHT BUT OPEN IN FULL DAYLIGHT



THE VENUS FLY-TRAP, SHOWING ONE LEAF CLOSED ON A PIN

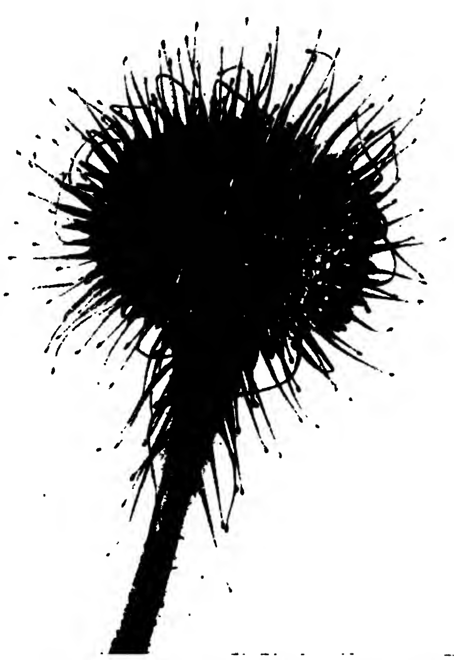
AN AUSTRALIAN SUNDEW WHOSE LEAVES CAPTURE AND DIGEST SMALL INSECTS

A still more subtle object has been suggested by some writers, namely, that the sudden movements of the leaves, which result from the vicinity of an animal that might otherwise feed upon the plant, may have the effect of creating such astonishment, or even fear, in the mind of such an animal that it would refrain from its contemplated meal. Whether such a thing actually occurs or not, it is difficult to say, but the suggestion is a very interesting one.

A movement which may be observed in almost all flowering plants is that which takes place at the onset of daylight, or at some varying period during the day afterwards. This is the opening of the passage to the interior of the flower. Very detailed observations have been made on the times at which this separation of the petals takes place, and the following examples, quoted by Kerner, may be noted here. In the case of the honeysuckle, the whole series of movements in the process begins by the lowest lobe of the corolla folding back, this being followed by the same thing in the other lobes, which liberates the stamens, and they spread out like fingers. This series of movements takes about two minutes. The evening primrose is still more rapid in its opening, the petals springing apart, and being wide open in half a minute. This may truly be described as the bursting open of the flower. In some cases this opening occurs quite quickly enough to be followed with the naked eye, and in one or two instances is accompanied by a slight noise.

With regard to the times during the day when these opening movements may be noted, Kerner gives the following instances: "There are flowers which open so early in the morning that they greet the first rays of the rising sun with fully expanded corollas. That common garden climber Ipomœa purpurea opens its buds at 4 a.m. Wild roses also open between 4 and 5 a.m. Between 5 and 6 many species of flax open. Between 6 and 7, willow-herbs; between 7 and 8, Convolvulus arvensis and tricolor. Between 8 and 9, many gentians, speedwells, and wood-sorrels, and the frequently cultivated Himalayan cinquefoil. Between 9 and 10, most tulips and opuntias open; between 10, and 11, the centaury and chaffweed. Between 11 and 12, Potentilla recta.

"From noon till evening comes a long interval. No plant is known in our latitude which, under ordinary circumstances, opens during the afternoon. Towards sunset, however, it recommences. About 6 p.m. the honeysuckle opens, shortly followed by the evening primrose and campion. Between 7 and 8 p.m., Hesperis matronalis and tristis, the Marvel of Peru, a few catchflies, and several thornapples. Between 8 and 9 more catchflies, a woodruff, and a species of tobacco. Between 9 and 10, the Queen of the Night the Mexican cactus opens."



A HIGHLY MAGNIFIED LEAF OF SUNDEW

When we come to consider the subject of plant defences we shall have to make reference to poisonous and insectivorous plants. One or two of these, however, must be noted here from the point of view of their movements. We may take those to which we have already referred. The whole of the genus sundew are excellent examples of plants whose movements are directed to the capturing of small insects. The plants themselves are common enough, and especially prevalent on damp soil and moorland. There are some forty species of sundew, all of which show as their most conspicuous character a slender red filament, that is club-shaped at its free end, and carries a refractile globlet of fluid. These filaments project from the upper surface of the leaf, the under aspect of which is smooth, and very often rests upon the damp ground. The filaments have been compared

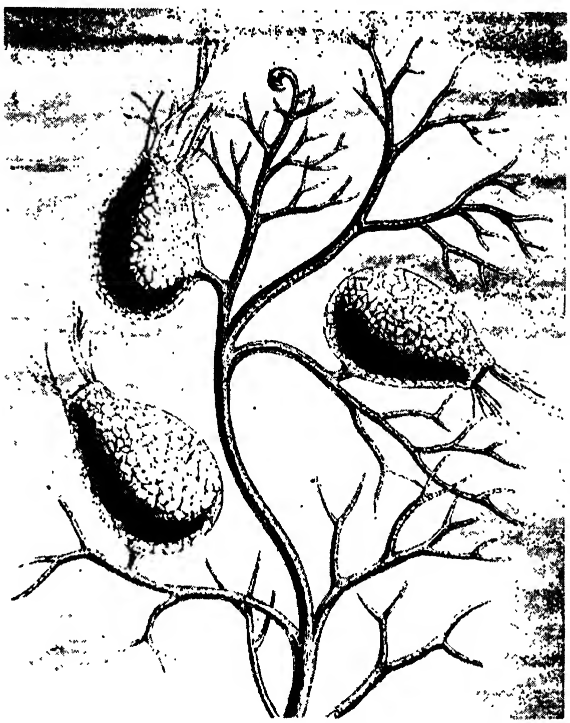
in their appearance to pins stuck in a cushion. They are various sizes, the shortest being in the middle of the leaf, the longest at the outer edge, and each leaf carries about two hundred of these little filaments. The club-shaped swelling at the end is in reality a gland, which secretes a clear globlet, that looks very like a drop of dew, but is really a sticky, viscous substance.

A wonderful example of plant intelligence is to be found here. The movements we have mentioned above in connection with wind and rain and dust are utterly ignored by the sundew. Experimentally, one may imitate these filaments with minute particles of ordinary foodstuffs, such as sugar, or with solid particles of sand, and so forth, and the only result is to increase the secretion of the gland, which assumes an acid reaction. The leaf itself, however, does not move, nor does there follow any attempt at digestion.

Let a small insect, however, in its search for honey, impinge upon the leaf and touch the gland, and — wonderful to relate—the composition of the secretion is at once changed, in so far as it becomes a digestive ferment, the object of which is, of course, to appropriate the unfortunate insect as food. Remarkable movements take place in the filaments, or tentacles, and they close in, so to speak, as the tips of the fingers would do if bent towards the palm of the hand.

Gradually all the filaments bend over towards the insect which has been caught in the sticky, glandular secretion, and in a time varying from one to three hours all of them are found bending upon it. No matter where the insect may alight, the tentacles move down upon it exactly to the right spot, whether it be in the centre or otherwise. Should there be two insects for the same leaf, at the same time, in different parts, then some tentacles will converge on the one, and some on the other.

The result of the whole process is that the captured little creature is covered with secretion and digested. The whole process of absorption is complete in a couple of days. What is left behind is carried away by the wind when the tentacles reassume their original attitude. Small midges are the usual victims of the sundews, but flies, and ants, and beetles also suffer a similar fate. As many as thirteen different species of captured animals have been found on a single leaf at the same time.



THE TRAPS OF THE BLADDERWORT THAT CAPTURE TINY AQUATIC ANIMALS

The really interesting fact about these wonderful, intelligent movements is not merely that they contribute to the nutrition of the plant, but that the movements take place in tissues other than those which are actually the first to be stimulated by the insect. In other words, there is a transmission, or carrying, of the original impulse from cell to cell through many cells at a speed which can be actually measured. This suggests at once to the mind an analogy to the transmission of a nerve impulse from the brain to a distant muscle in the arm or leg. How sensitive the leaves of the sundew are may be imagined when it is stated that "a particle of a woman's hair, 0·2 mm. long, and weighing 0·000822 mg., when placed upon a gland of Drosera rotundifolia, caused a movement of the tentacle belonging to the excited gland." A similar experiment on the human tongue would fail to give any indication of the presence of the hair, though the tip of the tongue is very sensitive.

LONDON'S VISITORS FROM THE SEA

HERRING GULLS MAKING THEMSELVES AT HOME ON THE THAMES EMBANKMENT

GULLS, WINTERING IN LONDON, PERPLEXED BY THE ICE IN ST. JAMES'S PARK

The photographs on these pages are by J. Williamson, A. J. R. Roberts, P. Webster, B. Hanley, P. Parkin, C. Reid, and others.

COAST BIRDS OF BRITAIN

The Useful and Graceful Sea Rangers which Add Interest to Seaside Holidays and Ocean Travel

MAN'S BLIND ATTACKS ON HIS HELPERS

MAN devises many inventions for bringing the sea into the midst of lives passed in inland towns. We are to have compressed ozone in cylinders, sea-water by pipe supply, seaweed in our milliners' shops, fish-scales in our artificial pearls, and now and again we see a half-hearted attempt to conduct an aquarium devoted to marine life. But nothing else brings the sea so near to London as the gulls at Blackfriars Bridge, and nothing more clearly demonstrates the meaning of seasonal migrations. Within recent years a few straggling gulls, driven inland by inclement weather, have grown into multitudes of established citizens that leave us only to seek their breeding haunts. They have become welcome parasites upon city life, dependent almost entirely for their livelihood upon the deliberate gifts of man. But it is never possible to forget that they are visitors from afar.

Occasionally one of the larger gulls may be seen to seize and eat a sparrow in the parks, and the cry has already gone up that gulls have "changed their nature," that they have taken to robbing game preserves, and are becoming a pest and should not be encouraged, but rigorously suppressed. The crime of the gull in eating a few of the harmful, if necessary, sparrows, and possibly a few other birds, is deemed as heinous as that of the majestic raven and the stealthy owl, and everybody knows that no game-preserver will tolerate these or any other birds that, rightly or wrongly, are suspected of thinning out the stock reserved for his gun. No; the gull is a visitor and a new one, yet not too new for the condemnation of the man with coverts monstrously overstocked.

We must treasure our inland gulls, whether they be on London's river or in her parks, or whether, like the calumniated rook, they follow the plough. For abundant as are its numbers out towards the sea, these are birds which fashion's sanguinary agents dismember to get plumes for pseudo-civilised women's hats; moreover, they are birds which offer an easy mark for the shot of the Yahoo from the cities sporting at the seaside. We have not got all the finest sea birds among our natives or visitors, but such as we have are very beautiful, graceful creatures, giving to cliff and coast, to estuary, loch, and lake, a life and charm and glory which all the art of man could not replace.

Some of our British coast birds, though in reality common enough, always carry a foreign suggestion in their names. Such, for example, is the cormorant, which is distributed fairly generally, if not abundantly, round our shores, and not infrequently seeks inland waters. The shag, or green cormorant, too, is a resident, though more restricted in habitat, and given, wherever possible, to nesting in caves instead of in the open as its larger congener does. In habits the birds are strikingly similar, and at a distance are hardly to be distinguished from each other, albeit the shag lacks the white patch upon the thighs which is a feature of the larger cormorant's nuptial plumage. That plumage also embraces a conspicuous crest upon the head.

Both birds are among the best of our feathered submarines. Passing the greater part of their time, except in the breeding season, upon the sea, they float with the head and neck slightly elevated above the water, but with the body submerged, "like a water-logged boat," says an ungracious description of this submarine with periscope above the waves. Often enough, however, the bird swims along at speed with its head and its neck submerged, gathering fresh toll of fish as it moves.

It is an old story that the cormorant is one of the birds which have long served man in the East as catchers of fish. The birds, when young, are trained to land with their catch, and a ring fastened round the gullet removes any temptation to swallow the prey. These are collected by the owner of the bird, who rewards the feathered retriever with a certain percentage of the catch. The cormorant possesses one special advantage as a trained snapper-up of fish for the table—it has an extremely capacious swallow, and a fish measuring a foot or more and of generous bulk, can lie reserved within the gullet of the bird.

CORMORANTS

The cormorant, though an adept, is excelled as a diver by some of our other birds, and of these the great northern diver is the most famous. This bird, which comes to us only in the winter, though from time to time we hear reports of its nesting in the Shetlands, has sacrificed much to its mastery of the waters. It can barely support its heavy, ill-balanced body upon land, but is so awkward and tottery that it is compelled to make its nest in close proximity to the water, so that without undue effort it may shuffle up to or down from the nursery of its young. Once on the wing its flight is bold and powerful, but nothing will induce the bird to rise unless it be migrating, and then it must flutter far on the crest of the waves before it is able to raise itself into the air. It lives by diving—that is, it catches its food by this means, and evades pursuit in the same manner. You watch it disappear, and expect it to reappear at A, but it pops up at Z. Of the four known divers, Great Britain has three, the black-throated and red-throated divers breeding on the Scottish lochs and working south with the advance of winter.

THE SHAG

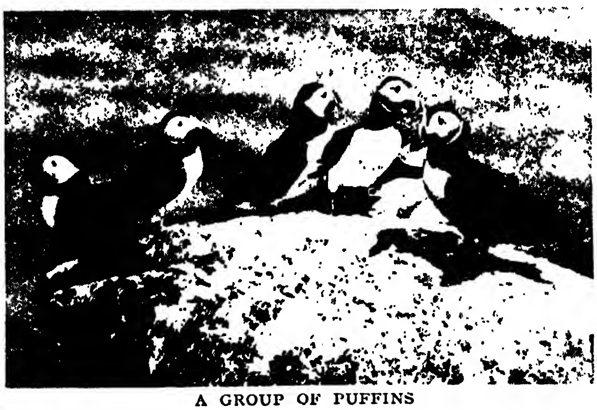
Birds such as these, nesting in close proximity to the sea, have no very difficult problem in getting their young to the water. It is different, however, when we come to the razorbills, the guillemots, and others that establish their colony two or three hundred feet up the cliffs which tower above the sea. How these birds get their bairns in safety to the waves, and how the puffin stores his fish in his bill while catching others, are matters over which naturalists still puzzle.

The razorbill belongs to the same order as the guillemots, the puffins, and the little auks, and all are grouped to form the auk tribe. The chief of these is, of course, no more. The great auk, like the dodo and the solitaire, has become extinct within comparatively recent times. The hope was long cherished that one or two of these birds might still survive, but there seems no doubt now that the last pair of these remarkable auks, the only flightless birds in the northern hemisphere, perished in 1844. They were at one time so numerous that expeditions were made to their breeding grounds, where they were driven in thousands upon thousands into stone pens, and slain for the sake of their feathers. Today an egg of the great auk realises over 300 guineas. It is believed that there are only seventy-two of these eggs in existence, and, with the exception of nineteen, these are in British collections. The great auks, which used their attenuated wings merely as paddles, after the fashion of the penguins, were formerly called by that name, but this title belongs now to those interesting birds of the southern hemisphere. Needless to say, the penguins, too, are flightless ; needless also to mention that they are being slain in enormous numbers for the sake of the oil which their bodies yield.

The other members of the auk tribe are happily well furnished as to means of flight. They have retained magnificent powers of wing while making themselves exceptionally expert in the water. The razorbill, known also as the lesser auk, is the sole representative of the typical auks now that the great auk is gone, for the true little auk is in another genus to itself. Razorbills live entirely at sea, day and night, except during the nesting season, when, together with other species of birds, they make for well-recognised breeding sites. In a well-favoured area may be found razorbills, guillemots, puffins, kittiwake gulls, and herring gulls, the latter claiming the most inaccessible rocks and ridges, and the razorbills being next in boldness in their choice of a nursery.

THE GREAT NORTHERN DIVER

With its well-developed wings, its splendid swimming power, and ability to keep the sea for months at a stretch, the razorbill need not fear the fate that overtook its greater cousin. Not that life is free from peril even for these powerful little birds. Razorbills, guillemots, and little auks perish sometimes in thousands round our coasts after protracted heavy storms. Whether they are simply buffeted to death or are starved through their inability to obtain due measure of food in such conditions is not at present known. Probably a diminished food supply results in reduced vitality, rendering the little victims less able to withstand the violence of the conditions to which they are exposed. Happily, there is no lack of these handsome birds at present, a remark that applies also to the guillemots and little auks.



A GROUP OF PUFFINS

The guillemots closely resemble the razorbill in general structure, though marked by a slenderer beak, and lacking the transverse ridges in the beak by which the razorbill is distinguished. They are to be seen from March till August in all our larger estuaries, swimming with delightful buoyancy, and diving with such rare celerity and elusive skill as to have earned the name of "the ducker." There is a slight but very significant difference between the nesting habits of the two birds. The "nest" of the razorbill is simply a depression in the rock, or it may be a hole or a cranny, but there is always some measure of protection against the disappearance of the single egg down the side of the cliff.

Now, the guillemot deposits its egg upon the naked rock, and often upon a sloping rock. Why this absence of care? The egg is most curiously shaped, thick-shelled, broad at one end, narrow and tapering at the other. The result is that, no matter how roughly treated, the egg does not roll away; it merely revolves in a small circle, like certain loaded toys with which we are all familiar. Every man who has bred birds may have seen the same effect produced in a small sterile egg which, towards the end of the nesting time, becomes "loaded" at the broader end, so that the egg will not roll, nor even lie lengthwise, but stands upright. It is this shape and "build" of the guillemot's egg that keeps the bird in the book of the living, for, with the rough-and-ready process of incubation to which the egg is submitted, the entire species would quickly become extinct were the eggs round and capable of being easily rolled away. It is worth while recalling that note has been made of an extinct auk which must have been closely allied to the guillemots, though in size it approximated more nearly to the great auk. This extinct

bird was, like the great auk, flightless. When it is stated that the remains were procured in the Miocene of Los Angeles, the student will appreciate the significance of the find. To discover a bird so specialised as to have developed wings, then discarded them in favour of penguin-like paddles, is a most remarkable circumstance.

We like to claim the little auk as British, but it is only at best a winter visitor to the more northerly coasts of the British Isles, though it may occasionally be found farther south, possibly blown thither by heavy weather. Its distribution is circumpolar, and it nests upon the cliffs of the far north. Many of us flatter ourselves that we espy the little auk when, as a fact, we see the puffin, which, in general build, in habit and in flight, it closely resembles if seen from afar. But there is one point in which the puffin differs not only from the little auk, but from every other bird, and that is in regard to the beak.

THE RAZOR-BILL

THE COMMON GUILLEMOT

THE LITTLE AUK

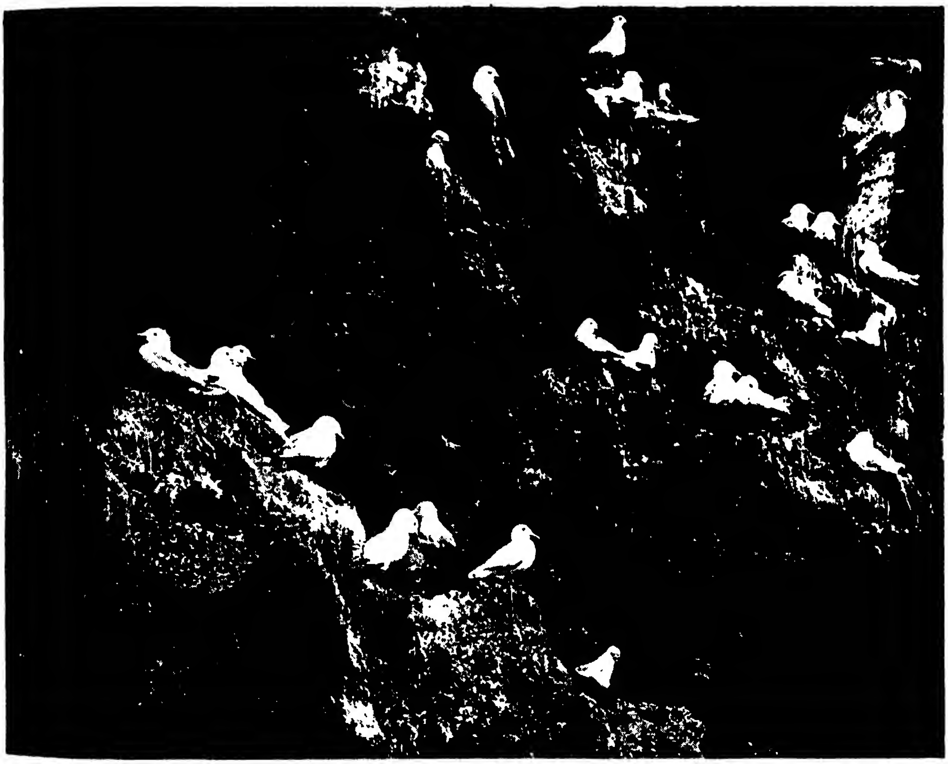
The puffin's beak is indeed one of the strangest features of British bird life. The adult assumes at the breeding season a bill of a size absurdly disproportionate to its small body. The bill is coloured a vivid scarlet and orange and blue, matching the hues conspicuous upon the muzzle of the mandril. But this gaudy colour-scheme relates only to the nesting season. When that is past the gay pigmentation ceases to attract, the massy bill shales off in horny plates, leaving a modest, sober-coloured little beak that, probably, is more effective for business than the brilliantly embellished contrivance it succeeds. Perhaps, however, the ampler proportions of the beak of nesting time may have some relation to the bird's habit of catching a number of small fish and taking them, all a score at a time, alive and wriggling to its young. As the little fish protrude from the puffin's jaws, actively struggling to escape, the naturalist is tempted to speculate as to how the bird, while securing the tenth, managed to hold the earlier nine in position in its bill. The puffin, though it is almost invariably to be found in company with guillemots and razorbills at nesting time, may wander farther inland than these others, and will gladly take possession of a rabbit hole, driving out the rightful owner with shrewd thrust and snap of that ever-famous beak.

Modern science has rejected the theory that the auks and the divers are closely related, and it will have none of the old belief that the gulls and petrels descend from the same stock. The gulls, if we accept the finding of most recent investigators, are simply highly developed plovers, specially modified to fit them for gaining a living from the sea. The gulls, it is now held, are related to the cranes, while the petrels are descended from an ancient stock not very distantly removed from the stork tribe. Be that as it may, the classification stands in this order: The terns, skimmers, and gulls constitute the first family, and the skuas the second family of the order gulls, or gaviæ, and we must follow that classification.

We have five species of terns among our summer visitors, the common, the Arctic, the roseate, the Sandwich, and the little tern, and each, needless to add, breeds with us. It is of importance for those who have the power to protect our birds to remember that, while our visitors may belong to widely distributed species, these

that come to us are really our own; and though on flying away they may upon arrival at their winter resort commingle with a host of birds similar to themselves, it is those which have been bred here that return. If we kill the British representatives of a species we do not get natural reinforcements from the same species from other lands. If all our speeding swallows were killed while leaving England this year we should not get a renewal of stock from the myriads that will congregate from various parts of Europe to pass the winter in Africa. Their home is the place from which they flew, and they know nothing of any land beyond the Continent of Europe. This fact is worth bearing in mind when dealing even with terns, for they have been abominably persecuted by the hunters for plumes for women's hats, and we have lost one species, the black tern, which formerly nested with us, but now comes only as a rare visitor.

The beauty and grace of the tern upon the wing are almost incomparable; and their popular designations, that of sea swallows and feathered arrows, sufficiently indicate their swift-darting flight and the rapidity with which they dive from the wing into the water in quest of the fish their keen vision has detected beneath the waves. The nesting habits of all the species are very similar. In the majority of instances the nest is a mere depression in the sand or shingle, but the lovely white-winged black tern, already mentioned, when it does accept our hospitality, makes its nest of marine vegetation in marshes near the sea. The common tern, with which we are all most familiar, is generally thought to scoop out its rough nest by wriggling its body, after the fashion of a bird taking a dust-bath, but a close observer affirms that the depression is formed with care by the bird using its beak for the purpose.



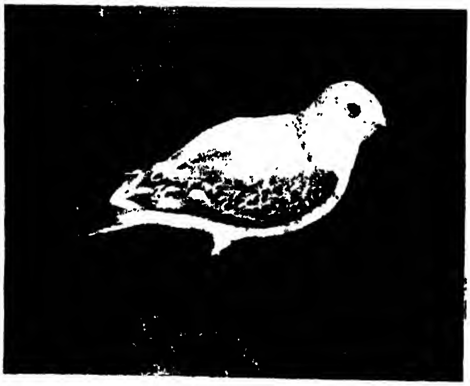
KITTIWAKES NESTING ON THE CLIFFS

Our gulls, of which Great Britain boasts several species, are in danger. The great black-backed gull admittedly attacks other forms of land life, in much the same fashion as raven and crow, but it levies toll only upon the sick and ailing animals or weaklings which might die from natural causes. It is now rapidly disappearing before the persecution of its human enemies. Other species are in almost equal danger, as some

recent correspondence in the public Press has brought home to the minds of all of us. The Southern Sea Fisheries Committee and the National Sea Fisheries Protection Association have addressed the Isle of Wight County Council, desiring that, "on account of the great destruction caused by the large increase of gulls amongst the fry of the several species of fish in the estuaries

COMMON TERNS

of the Southern Sea Fisheries district, the county councils of the Isle of Wight, Hants, and Dorset be asked to remove from the list of protected birds all species of gulls, with the exception of the tern." Opposition to this unfriendly suggestion was forthcoming from several influential quarters, and the body to whom the recommendation



THE COMMON GULL

was committed returned a highly effective answer. They refused to accede to the application, saying that they were not satisfied that the gulls are responsible for injuring the interests of bonâ-fide fishermen, and that they strongly object to anything which would exterminate a bird so useful as a scavenger both on sea and land, a bird which acted as a warning signal to sailors who are nearing the coast in foggy weather.

This was altogether admirable. For fish are almost incredibly prolific. The cod-fish is known to produce over 9,000,000 eggs a year, and the conger-eel 15,000,000. If all the eggs of either of these fish hatched, grew to maturity and reproduced, the sea would become one solid mass of them. The secret of

THE ARCTIC TERN

this apparently excessive reproduction is that enemies such as the gulls have to be reckoned with, and are provided for in Nature's scale. It is an impertinence for man suddenly to decide that he alone shall do the catching and killing and eating, and that any living thing caught upon "his" ground shall die. There is

THE BLACK-HEADED GULL

food in plenty for the gulls, and they earn their keep.

The newest cry against these birds is that "they have changed their nature," taken to nesting in heather and bushes inland, and to eating corn. A few may have done so, but a whole order is not to be harried for the local peculiarity of a few. And so utterly untrustworthy is the evidence of the

average farmer against any bird which he says has taken to eating his corn that any court of ornithologists would demand a close examination of the crops of a number of the indicted birds before accepting such testimony as condemnatory. We know, in human experience, that for some men to look over a fence is to be held guilty of stealing a horse, and a bird's alighting in a field in quest of grubs or other insect food gives clear proof to the prejudiced of an unlawful intention against crops.

It fortunately happens that gulls were among the birds into whose habits the Board of Agriculture inquired four years ago, and the result is to give the gull, with the rook, a very fine testimonial. We cannot do better than pass on the finding of the Board. Drawing attention to the enormous number of leather-jackets, a most destructive pest, which recently devastated the Dee pasture lands, the report states, "When the crane-flies [the perfect form of the leather-jacket] appeared, they were attacked by flocks of black-headed gulls, and to such an extent did these wage war against the insects that their pellets or castings were left scattered over the land in hundreds, looking like little bundles of tightly packed grass. One of these pellets, upon being soaked in water, was found to contain the remains of about 400 crane-flies, and 1000 of their eggs, the latter having evidently been taken while yet in the body of the parent. Each pellet probably represented a single meal, and there can be little doubt that each bird would make at least ten meals daily of these insects. If this were so, a single gull would be accountable for the enormous number of 4000 crane flies and their eggs per day, making an aggregate of 28,000 per week. As the gulls flocked together in hundreds, the number of insects which they devoured may be better imagined than described."

A FLOCK OF LESSER BLACK-BACKED AND HERRING GULLS

Although the investigations lasted during seven months of the year, in not a single case was a grain of corn or any other cultivated crop found in a bird's crop. Common gulls' contained the remains of fish, molluscs, and grass; herring gulls', vestiges of small crustaceans, and small fish, and one retained the leg-bones of a dog, showing that the bird had been true to its reputation as a snapper-up of carrion. The dreaded great black-backed gull and the lesser black-backed variety showed no evidence more incriminating than a diet gathered in the sea or upon the shore. The examples chosen here were taken promiscuously, with no desire to extenuate or mitigate. They were representative cases, and are a stunning answer to the allegation of corn-stealing made, obviously upon insufficient evidence, against an entire genus.

Gulls in the main, are fish-eaters and

scavengers, with a penchant for insects, the latter taste inducing great numbers of black-headed gulls to wend their way inland, where they are a sovereign asset on ploughed land and upon pasture. The smallest of our gulls is the kittiwake, a bird resembling in form the herring gull, but only 15 inches in length as against the 23 inches of the other species. It is a resident, and breeds upon cliffs as already mentioned. The handsome black-headed gull is next in size, being less than an inch longer than the kittiwake. These birds, however, prefer inland marshes, whence they disperse, some to the fields, some to the sea coasts, some to the estuaries and great tidal rivers. It is his joyous guttural chuckle that has given to this black-headed bird the not inappropriate name of the laughing gull.

The nest of the herring gull is made upon dizzy headlands and inaccessible rocks, whence it descends with a great swoop to snatch its food from the waves or to paddle about the shore at the tide-line, or to share with the laughing bird the spoil of the fields. The lesser black-backed gull occasionally consorts with the herring gull at the nesting colony, or it may form one exclusively peopled by its own species, but in general habits it is the herring gull over again. This is one of the most numerous of our gulls, while the great black-backed gull, a bird of 30 inches length, is now the most rare of resident gulls.


THE FULMAR PETREL

The so-called common gull is in reality less common than the former of the two species just named, and does not nest south of the Scottish border, although out of the breeding season it flocks in large numbers down the English coast and into the fields. Among visitors are counted some half-dozen other gulls, the ivory, the glaucous, the Iceland, the great black-headed, the little, and Sabine's, but these are probably storm-carried birds; they are not true exceptions to the rule as to migrations following definite lines. It is conceivable that were a few birds from colder latitudes blown to our shores they might in favourable circumstances nest, and that their young might return after migration, and so give us a new species. But when so-called new birds regularly appear, it may generally be found that they are descendants of ancestors which once made British shores their home for part of every year.

Seeing that word has gone forth against the gulls on the score of their presuming to have recourse to their natural diet, it is a wonder that we have heard nothing to the discredit of the gannet, or solan goose, a majestic white bird, instantly recognisable from its long, pointed beak and the curious colouration of the feathers round the eye. Here is a fisher indeed, with none of your land produce to eke out his diet. This is the bird whose multitudinous numbers at breeding time make the Bass Rock and St. Kilda appear to lie under a dense covering of snow, while the air around is so crowded with the birds that the sunlight is blotted out from the observation of the watcher on the water below.

The gannet is a creature of exquisite grace in the air, facing with ease a wind that will send the gulls ashore. As it espies the fish the bird rises swiftly a little way, turns, like a duck diving, then descends with a prodigious plunge into the water, fearless of shock, from the fact that its breast is furnished with air-sacs which shield it from what to any other bird would be a dangerous blow from the momentarily unyielding water. The gannet rides high in the air to spy out the fish beneath the surface of the water; and it is so good a look-out that fishermen, waiting for the coming of the herring, put out with their boats when they see the gannet make its plunge.

None of the gull family is lacking in courage or boldness. The herring and other gulls try to rob the terns of their fish, but the skuas go one better, and rob the mighty gulls themselves. These skuas are the vultures of the deep. Exclusively oceanic except at breeding time, they eat carrion floating upon the waters, but rely in chief upon securing the prize of other birds. Armed with a cruel, hooked beak and powerful tearing claws, they attack the gull which is sailing home with its crop full of fish. Good flier as the gull may be, he is helpless before the swoop of the skua,

THE ONLY HOME THE SEA-BIRD KNOWS

GANNETS AND THEIR YOUNG ON THE BASS ROCK DURING THE NESTING SEASON

FACING PAGE 2621

and either to lighten himself, or as a peace-offering, he must eject from his mouth the fish which he has swallowed. As the fish falls from the beak of the gull, the skua darts down upon it with such speed that it secures the booty before it can fall into the water. Skuas are the fiercest of all the marine birds, and are the savages and cannibals of the nesting time. They live then upon the eggs and young birds of other species. Happily, the young skuas are so savage and fight so viciously among themselves that they keep their numbers down to reasonable limits without the aid of extraneous influences. Two species the great skua and Richardson's skua—breed in British waters.

Turning to the petrels, we note first the fulmar, the largest of our natives, a fine swimmer and powerful flier. When once its solitary chick is reared the fulmar roams far out to sea, the commonest of oceanic birds. Whether its comparative absence of enemies and consequent easy life have resulted in the female's laying only one egg, or whether the ability to lay but that one has caused the fulmar to take to its present form of life so far from land, is not to be decided. There are other sea birds, as we have seen, which lay but one egg, and they do not put out to sea.

THE GREAT SKUA

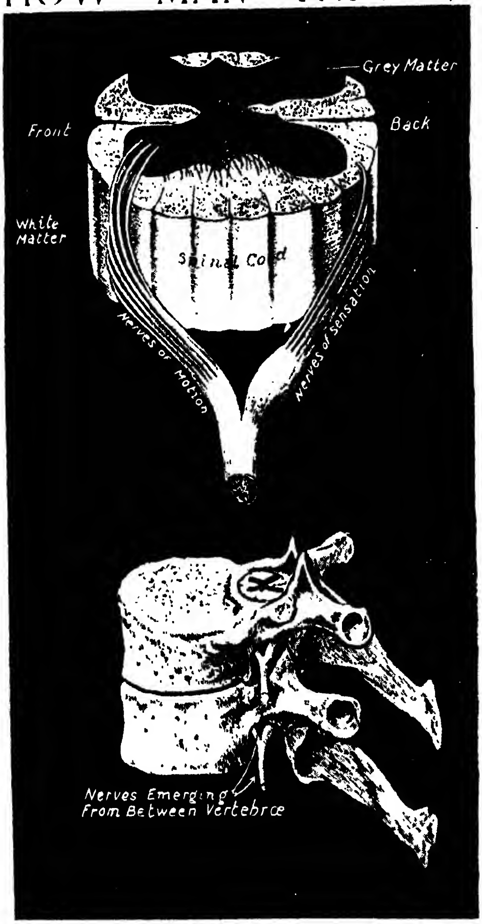
The stormy petrel also goes far to sea, returning to land only to nest. This is the smallest of all web-footed birds, and a model of power, both in the water and in the air. Month after month it keeps the sea unweariedly. Small in body as a sparrow, and resembling in shape and colouration a house martin, it is ever seeking that food which no man has been able to identify. The stomach never contains anything but oil, and of what that is the product we cannot say.

We see little of the stormy petrel, and must content ourselves with a commoner member of the group, the Manx shearwater—not because it is more numerous than the fulmar or stormy petrel, but because it keeps nearer land. It shares one or two peculiarities with the petrel. In the nesting time the bird is nocturnal in its food-quest. When flying over the water it seems to walk upon the waves, sustained by its wide, outspread wings. Its trick of cutting close above the waves gives it its name of shearwater. Indeed, the name "petrel" is a corruption of Peter, and commemorates the Apostle's attempt to walk upon the water.

Perhaps the eider duck should be included in the present chapter. It is a sea bird pure and simple, coming to our coast only to breed. It is the sea duck, a proficient diver, and capable of taking its food from the ocean bed at a great distance from land. Its breeding habits are a matter of common knowledge. The female lines her nest with the beautiful down with which her breast is covered. Where the bird's down is thus deposited the clutch of eggs and the nest are taken. The female lines a second nest, and this, too, is taken. A third nest and clutch of eggs are prepared, but for this the male bird must divest his breast of down. This third nest is permitted to remain, so that the species may be perpetuated. The last nest is recognisable from the fact that, whereas the down of the female is pure white, that of the male is tinged a faint yellow. It is to be hoped that the yellow feathers in the nest really do act as a warning, but commerce is often without conscience.

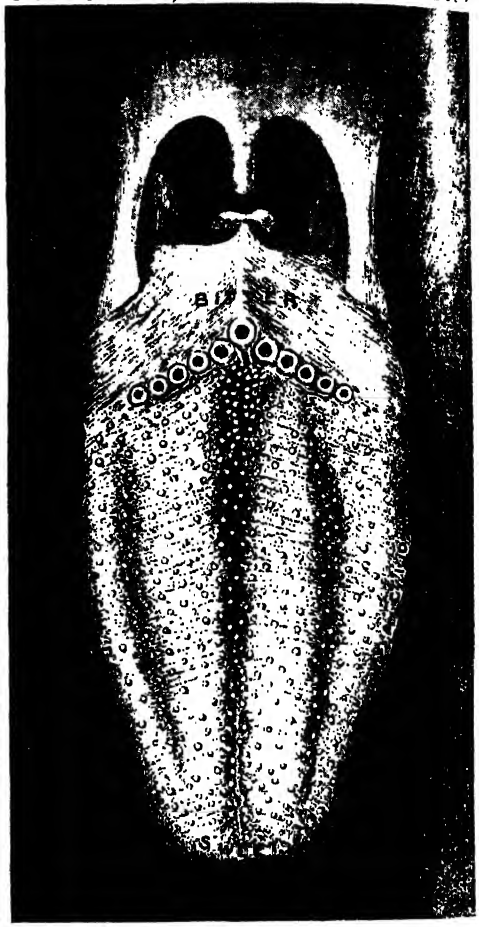
We shall meet other water birds in a later chapter, fresh-water birds and sea-going birds, princes of flight like the albatross; flightless birds, such as the penguin. Here we have a group of glorious birds which add to the attractiveness of the seaside for us all, or make ocean travel more delightful. Let us hope that many such bodies as the Isle of Wight County Council will return courageous answer when proposals are made to exterminate these interesting and beautiful creatures.

HOW MAN TASTES, SMELLS, AND FEELS



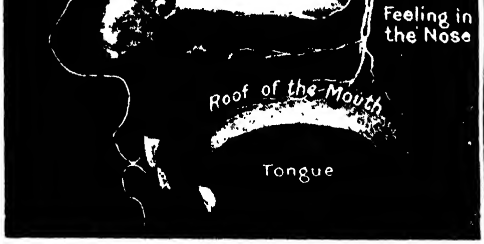
HOW THE NERVES RUN INTO THE SPINAL CORD ON THE WAY TO THE BRAIN

The lower drawing shows how the spinal cord rests in the backbone, and how the nerves pass in and out, those of sensation passing into the spinal cord, as shown in the magnified section above.

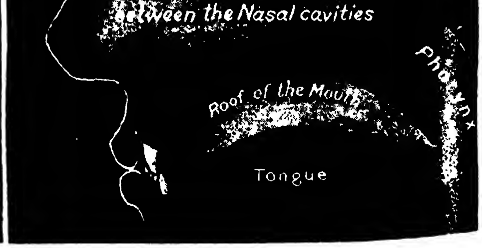


THE AREAS OF THE TONGUE IN WHICH THE CELLS OF TASTE ARE DISTRIBUTED

The tongue is covered with various types of taste-bulbs, ... the distinct types that appreciate the sweet, the acid, ... bitter being found in the areas marked on the diagram



THE OUTER SIDE OF THE NOSE, SHOWING THE NERVES OF SMELL AND FEELING



THE INNER PART OF THE NOSE, SHOWING THE FIBRES FROM THE OLFACTORY BU...

MAN'S LESSER SENSES

Touch, Smell, and Taste, and Their Seats in the Skin, Nose, and Tongue

THE FIVE GATEWAYS OF SENSATION

STUDENTS of Bunyan's "Mansoul," and those who remember the domestic teaching of their youth, are acquainted with the idea of the soul, or *psyche*, of man as having "five gateways of knowledge," or five avenues of sensation by which the mind makes the acquaintance of the outer world. Modern science can by no means assent to this limitation of our "gateways of knowledge" to the small number of five, but it is convenient to take them in something like the old order, for these five senses are well defined, and each of them has a definite sense-organ, situated at the end, or ends, of its special nerves, and constructed for the reception of certain special kinds of stimuli. Vision, hearing, touch, taste, smell, obviously correspond to five definite "gateways"—eye, ear, skin, tongue, and nose.

Of these "five senses," as we may now inadequately call them for the last time, two are pre-eminent on account of their practical value, their range of capacity, their subtlety of employment, the perfectly astounding complexity of their respective end-organs, and the psychical depths to which they are capable of leading. These are, of course, the eye and the ear, to which the two preceding chapters of this section have been devoted. In the hierarchy of the senses these two stand co-equally first. The body of man has largely devoted itself to the construction of the machinery by which the possibilities of these two senses could be developed to the utmost. The skin or the tongue of man shows little, if any, superiority in structure to that of many humbler animals, and his nose is clearly d generate, but the construction of his eye and ear is unexampled for delicacy, and for the extent and richness of its nervous representation in the cortex of the brain. The evident reason is that these two gateways open upon a far more valuable and varied range of possible knowledge, and that the apparatus for receiving this variety of knowledge has been devised accordingly.

We are therefore right to call touch, smell, and taste the lesser senses, as compared with vision and hearing, but this is not to say that they are not worthy of careful study, for they contribute many important ingredients to the sum total of our mental life; and the first, in particular, has special claims to respect, partly on account of its antiquity, and partly because several distinct senses are concealed under the name of touch, though all have their special sense-organs in the skin.

The various sensations which have their seat in the skin are usually called the cutaneous sensations, and the best and most scientific way in which to study them is by direct observation and experiment upon one's own skin. Science affords few better illustrations of the contrast between what we think we know of familiar things and what they reveal when they are seriously studied. Most of us would probably say that we "naturally" knew all there was to know about the feelings of which the skin of our hands was capable, but the reader will shortly decide for himself whether that opinion is justified.

Within recent years it has been clearly proved, and can be verified in a few minutes by anyone who will take the trouble to do so, that our cutaneous sensations are not less than four in number. They may be more, and we shall perhaps see that there is reason to suppose so, but as to the existence of four distinct senses at least there is no doubt, nor as to the existence of a corresponding number of special areas, organs, and nerves in the skin. We think of the skin as a continuous covering, all of a piece and all the same. We should be astonished if it were so constructed that its

different parts had different colours. We should then see the skin as a kind of tiny mosaic or patchwork of at least four distinct colours—say, black, white, red, and green—all dotted regularly-irregularly over the entire surface of our bodies; and in this case each colour, wherever a spot of it occurred, would indicate a particular form of sensibility which could be felt in all spots of that colour, but in no others. The problem for the skin has been to provide the mechanism for these four senses, everywhere at once, so that every part of the skin should be able to serve the needs of all of them. Strictly speaking, that was an insoluble problem, for one kind of apparatus is required for touch, another for temperature, and another for the sense of pain (to take these instances without further criticism for the moment); but the problem has been practically solved by making the respective spots exceedingly small, and mixing them up very thoroughly, so that, though no one spot of skin can really feel, say, both pain and pressure, yet the spots are so tiny and so closely packed together that it is as if the whole skin could feel everything that is required.

The Different Forms of Sensation Felt Through the Skin

This, together with the fact that no external indication like difference of colour is there to help us, explains how it is that only within the last few years have men discovered the simple facts which have been under and on their own noses ever since men existed at all. According to the best authorities of the present day, the four cutaneous sensations between which the whole surface of the skin is divided are the sense of touch or contact or light pressure, the sense of heat, the sense of cold, and the sense of pain. No doubt we are at first inclined to protest, and say that these things cannot always be so distinguished, but that is obviously because the different spots of skin concerned lie so close together, and are so tiny, that under many conditions what we feel, and feel as if it were single, is really a mixture of two or more of these senses. Painful heat and painful cold are obvious instances of this, to say nothing of the apparent fact that sense of heat and cold is all one; yet it can be proved that these various senses are really distinct in every way. The local proof, in the skin itself, will be laid before the reader shortly, but in the first place we must briefly refer to another kind of proof, derived from the study of nervous structure and nervous disease, which has long foreshadowed the recent discoveries regarding the skin itself.

Though we have carefully discussed the brain, very little has yet been said here about the spinal cord, the downward continuation of the brain into the spinal column, though, from the historical point of view, it is more correct to describe the brain as the upward expansion of the spinal cord into the cranium. The spinal cord contains some grey matter, some of which is concerned with motion and some with sensation, and we have seen that this grey matter is involved in what is called reflex action. The rest of the spinal cord consists of white matter or nerve-fibres, running up and down its length. This white matter has been found to consist of a large number of quite distinct tracts, as they are called.

The Experimental Value of Accidents to the Human Body

One tract or bundle of fibres will be conveying impulses downwards to the muscles from the brain, another will be conveying impulses upwards from the skin, and many other parts of the body, to the brain, and so forth. Various forms of disease, and such accidents as fracture or dislocation, or bullet wounds, etc., have made and still make a variety of "experiments" upon the spinal cord, injuring it in part, so that certain consequences follow; and in such ways as these it has been possible to distinguish a large number of tracts, and to discover their special functions. Thus there is a well-known though rare disease of the spinal cord in which the accumulation of fluid within its central canal brings a fatal pressure to bear upon certain strands or tracts in its substance, and we sometimes find that the patient, though he can appreciate touch and heat and cold, is entirely insensitive to pain. A pin is felt to touch him, but does not hurt him.

The Discovery of the Different Strands that Make Up the Spinal Cord, and Their Uses

Such discoveries as this have led us to the knowledge that there are totally distinct tracts in the spinal cord, with distinct connections and distributions in the brain, which nevertheless all serve the skin; but while pain, as we loosely but conveniently say, runs up one tract and only up that tract (so that, if it be damaged, pain cannot be felt), heat runs up another, cold runs up a third, and touch up a fourth. So far as the spinal cord is concerned, these four senses are thus just as distinct as are the senses of hearing and vision, each of which has its own special tracts of nerve-

tions in the substance of the brain. And just as nervous disease or accident or certain poisonings, such as nicotine poisoning, may affect the visual tract only, or the auditory tract only, so disease or accident or poisoning may affect the heat-tract or the pain-tract only in the spinal cord. All this is unquestionable evidence as to the justice of our claim that the skin, though it appears to be only a single thing, is yet the seat of four distinct senses, which on their much humbler plane have as good a right to be distinguished as vision and hearing have. At this point, however, the judicious reader will certainly ask whether we can also point to the brain and say that there upon its surface is the centre of touch, and there the centre for pain, and so forth, just as we can point to the visual and auditory centres respectively.

Here it must be admitted that our knowledge is as yet very inadequate. The problem of "cerebral localisation," the modern version of phrenology, is still very far from solution in regard to the cutaneous sensations. Hitherto the evidence seems to indicate that the various cutaneous sensations are all represented in the same area or areas of the cortex, apparently largely coincident with the area which is concerned with voluntary motion.

The Skin a Patchwork, in which Different Sensations are Felt by Different Parts

But, in the judgment of the present writer, this fact is perhaps not so disconcerting as is generally thought. Until we examine the skin very closely, we fancy that the whole of the skin is capable of feeling all four cutaneous sensations, the fact being that the skin is a patchwork so closely assembled that though only one-fourth, say, of the skin can really feel any one of these sensations, yet for practical purposes it is as if all four were represented everywhere in the skin. The suggestion may be made that a corresponding state of things will be found to exist in the cortex when we are able to examine it microscopically and chemically in a corresponding fashion to that which we are about to describe for the skin. It may then be found that the cortical area concerned with these senses is itself an assemblage of parts, thoroughly well mixed, so to say, each of which has nevertheless its own specific function and none other, just as we saw in the case of the nervous apparatus of sight or hearing, which replies in its own unique way to *any* stimulus to which it replies at all. If so apparently simple a structure as the skin can really be an assemblage of (at least) four distinct kinds or parts, each with a special function, there is no difficulty in believing that the area of the cortex, which deals with the cutaneous sensations, has a corresponding complexity. It has millions enough of nerve-cells, of many different kinds, to support such an assumption; and it may yet be shown, for instance, that the cells in one layer of this area are concerned with the impulses coming up through the pain-tract from the pain-spots in the skin, while the cells in the layer above or underneath it may be similarly concerned with touch or heat or cold. But exact knowledge at this point is still to seek.

Some Spots on the Skin Sensitive to Cold and Others Not

Let us now return to the skin, and try to appreciate the experimental evidence which proves that it is an anything but crazy patchwork of tiny areas, each one of which can receive and transmit a special kind of stimulus and that alone. We cannot do better here than quote the directions to the elementary student given by Dr. McDougall, the author of the best text-book for that purpose:

"Let him touch gently a hair on the back of his hand. This will excite pressure-sensation, for the roots of the hairs are surrounded by the minute sense-organs of the pressure sense. Then let him choose a small area of skin devoid of hair—say, the palm of the left hand and prod it gently with the end of a moderately fine hair, working over it systematically. He will find, if the hair used is of appropriate length and rigidity, that some spots readily yield pressure-sensation, while others are insensitive to this gentle stimulus. Let him mark these spots with an aniline pencil. Then let him take a blunt metal point (or a blunt pencil-point will serve the purpose), and work over the same area, drawing the point in close-set parallel lines across the surface. He will find a number of spots which, when touched, give distinct sensations of cold, all other parts giving no such sensation.

Some Spots that are Sensitive to Heat and Others that are Not

"Working over the area again in similar fashion with the blunt metal point warmed to about 45° C., he will find a third set of spots from which alone sensation of heat is evoked. Lastly, let him take a short horse-hair, mount it in the split end of a matchstick, cut it across obliquely half an inch from the handle, and then prod over the same area of skin. He will find that smarting or pain-sensation is evoked at a fourth set of points, and not elsewhere."

One concluding and conclusive experiment is worth making here. Let us recall the famous doctrine of Johannes Müller, that the sensory apparatus of each sense is *specific*, so that if the ear be excited by sound or inflammation, or the eye by light or a fist, the results must be hearing and vision respectively. If such a doctrine is to be proved, we should find it possible to excite certain senses by something other than their natural stimuli, and yet produce the customary sensation. This we have already seen to be true of various senses, which can be excited by electricity. Thus the eye can be induced to *see* in the dark by means of electricity. If the tongue be stimulated by an electric current, the result is taste, and the particular quality of taste experienced will correspond to the particular and specific tendency of the part of the tongue which is being excited. Similarly, when an electrical current traverses the mucous membrane of the nose, we experience sensations of smell. But the skin affords us a more striking example than any other of the famous discovery of Müller.

The Curious Fact that Heat on a Cold Spot of the Skin Feels Cold

In the series of simple experiments above described, we have already ascertained and localised the "cold spots" of the skin, those, namely, where alone sensations of cold are experienced. We saw, also, that the skin contains heat-spots, which we identified by the use of a metal point made fairly warm, though not so warm as to complicate the case by also exciting the pain-spots. What will now happen if we apply this warm point of metal to a "cold spot"? If the experiment be delicately and accurately made, we find that a sensation of *cold* is experienced as a result, even of stimulation by heat. This is known as paradoxical sensation of cold. A paradox is an apparent absurdity (not a real absurdity, as we often misuse the word to mean); and there is no better instance of a paradox than this production of the sensation of cold by the application of heat to a sensory organ which was specifically constructed so as to give us the sensation which we call cold, and no other. The parallel to the other senses is complete, and the law of Müller is triumphantly and strikingly vindicated.

Finally, it remains to ask whether there are special organs in the skin which serve these special sensory functions. Careful microscopic investigation shows us some peculiar structures, the Malpighian and Pacinian corpuscles and others, named after their respective discoverers, which can be found notably in the tips of the fingers, in the sensitive tongue and claws of such birds as the parrot, and elsewhere. But all the structures which anatomists have been able to discover in the skin of man or any of the lower animals seem to be exclusively concerned with the special sensation of touch or pressure. Though we can identify hot and cold spots and pain-spots by the simple method above described, the microscope cannot identify any special structure in the skin according to the various functions of the various spots. Nor can much be said as to the functions of the ridges on the skin of the fingers in this respect.

The Difficulty of Tracing the Separate Areas of the Four Senses of the Skin

Herbert Spencer made the very reasonable suggestion that the special structures associated with touch would be found to be arranged along these ridges, but in point of fact the "touch-bodies" were found to be more abundant in the grooves between the ridges, and the only function which has yet been certainly attributed to these ridges is for purposes of criminal identification! But though we cannot describe, in the skin, special organs like the eye and the ear, or even organs so distinct as, say, the rods and cones of the retina, at any rate we have definitely proved that four distinct senses reside in the skin, that each has its own areas, its own nerves, and its own path in the spinal cord; and we may yet be able to say that each also has its own area, or its own host of tiny areas, or its own layer of nerve-cells, upon some part of the cortex of the brain.

Taken as a whole, the four cutaneous sensations are obviously of very high importance, which we may specially define, from the standpoint of man's place in the world, as protective rather than instructive.

The Lower Plane of the Protective Skin-Senses Compared with the Eye and Ear

Doubtless they are in part instructive, and are to be regarded as a fourfold "gateway of knowledge," but when we compare them with the eye or the ear, which afford us such a limitless range of information, about the structure of the stars, and the thoughts of our fellow-beings, we see how clearly the cutaneous sensations belong to a lower plane, and may be defined as primarily protective, rather than instructive, in function. The fact that something hurts us is useful not so much in teaching us its nature, which is probably very simple and only has the quality of coming to a sharp point or edge, as in causing us instantly to withdraw from

what may injure our life and health, and to avoid such a thing in future. If we come to study the nature of the pin or the knife in any deeper way, we require to use the eye, which is for instruction, while the skin is for the preliminary and essential but lower function of protection. Similarly, our sensations of pressure and heat and cold are essentially protective in their utility.

The Four Qualities of Sensation Noticeable in Taste

The sense of taste has its end-organ in the tongue. A few taste-bulbs, as they are called, can be found scattered upon the soft palate and sides of the throat, and are not to be despised by anyone who is so unfortunate as to be deprived of the tongue, but for our present purpose they may be ignored. When the covering of the tongue is studied microscopically we find various types of taste-bulbs, evidently comparable to the touch-bodies in the tips of the fingers, and to those touch-bodies which are also found in the tongue itself. The distribution of these taste-bulbs, which are to the sense of taste what the eye is to vision, or the inner ear is to hearing, can be shown to correspond to the particular aptitudes of the various parts of the tongue. In the case of the eye we saw that there are probably four distinct or elementary qualities of sensation which can be excited through it. In the case of the skin the number was also four. In the case of the tongue the number happens to be four again. Of course, there is no reason to suppose that this is any more than a coincidence, but it is at least a mitigation of the task of memory that eye, skin, and tongue correspond to four elementary sensation-qualities apiece.

Do Sweet, Sour, Bitter, and Salt Exhaust Our Elementary Sensations of Taste?

The reader should really consider his own recollections before he proceeds. At first, remembering the almost innumerable articles of diet, meat, fruit, vegetables, salts, sauces, wines, spirits, medicines, and what not which have assailed his palate, he will confidently say that to limit our varieties of taste to four is truly ridiculous. But on further consideration he will probably agree that what he has been reviewing is scarcely so much a variety of tastes as of flavours; and he will readily admit, if he has ever had a bad cold, that flavour is a matter of smell as well as of taste. Let him now try to exclude all questions of odour from his recollections, and confine himself purely to taste.

How many different kinds of pure taste can he name? Here, again, as in the case of the eye and the skin, we must not be so positive as to exclude the possibility of further refinements of our knowledge, but it is probable that sweet, sour, bitter, and salt really cover all our elementary taste-sensations. They are as genuinely distinct as the various sensations which have their end-organs in the skin. Thus, as we have already hinted, if an electrical current be passed through the tip of the tongue, the sensation excited by it is that of a sweet taste. If it be passed through the upper part of the back of the tongue the sensation excited is that of a bitter taste. Plainly, the law of Müller holds good here as elsewhere. It may be noted, as further anatomical confirmation, that different sensory nerves supply the front and back parts of the tongue respectively, and the taste-bulbs found in the various parts of the tongue, tip, edge and back part of upper surface, are largely distinct in structure. There is a good deal of intermixture among them, no doubt, but the separate sensations are kept much more to themselves than in the case of the skin.

An Analysis of the Taste of Lemonade into Simple "Notes"

Anyone can prove for himself that sweets taste best in the front of the mouth near the tip of the tongue, and children who are not worrying about appearances have no hesitation in eating sweets in a fashion which bulges the lips forwards, not in order to be rude, but because sweets taste best there. But, on the contrary, when we amateur-wise swallow a dose of quinine, and it first encounters the tip of the tongue, we think that really it is not half so bad as we expected. Then we swallow it, or try to, and plaster the back of the tongue with it, whereupon we discover that our worst anticipations were inadequate.

Except when we make such experiments, and in a few other cases, our sensations of taste are usually excited in various combinations simultaneously. This largely explains how it is that, though we have only four elementary qualities, we can distinguish so many different tastes. Lemonade tastes like lemonade, for instance; we can identify and remember it. But if we consider our sensations in this case, even the least gifted of us will be able to perform a feat parallel to that of a musician who hears a chord, and can identify the various notes which compose it. We can clearly identify two simple "notes," so to say, in

the "chord" of taste which we call the taste of lemonade. One of them is sweetness, and the other is acidity. If we care to experiment, applying the lemonade carefully to the tip and the edges of the tongue in turn, we can bring out these constituents of its taste with more prominence; and if a bitter ingredient has been included in the brew from the pips or the peel, the back of the tongue will identify that as a third ingredient of the "chord" of lemonade thus "modulated."

Points of Similarity Between the Senses of Touch, Taste, and Smell

The end-organ of the sense of smell is constituted by a certain restricted portion of the mucous membrane or lining of the nose. We should be astonished at the extent of this lining if it could be spread out flat before us, but its great area is mostly concerned with the purification and modification of the air before it enters the lungs. The nerves of smell, or olfactory nerves, only run to a relatively small area of this mucous membrane in the upper part of the nose—a position which explains the fact that we smell much better when we "sniff" for the purpose, for sniffing carries the current of air upwards to the olfactory membrane, as it is called.

For let us particularly note that taste and smell, which are often called the chemical senses, are closely allied to the sense of touch in the skin, with which they are doubtless connected historically and evolutionally, in that actual *contact* is a necessity for their action. The eye is affected by ether-waves, and the ear by sound-waves, but the tongue and nose are not affected by any kind of waves, though the swimmer who inhales at the wrong moment may be of a different opinion. The tongue and the nose are affected by contact. If we suppose that this is not true of both of them—for though one cannot taste at a distance, one certainly can smell at a distance—we have to learn that smell depends upon contact no less than taste does. Actual atoms or molecules of the odorous substance must enter the nostrils and come into actual *contact* with the olfactory mucous membrane before the sense of smell can be aroused.

A Grain that Will Perfume a Room for Twenty Years

This is indeed one of the classical illustrations of the almost infinite divisibility of matter, and the minuteness of the atoms of which it is composed, for a single grain of musk will perfume a room for twenty years; and it has been proved that in this and all such cases actual portions of the odorous substance must be in process of emission and distribution all the time, if it is to be smelt. The fact clearly extends our idea as to the number and the minuteness of the atoms of which the grain of musk, or whatever it be, must be composed. The special point for us here, however, is that when we perceive the odour of anything "at a distance," we are not responding to vibrations it has set up in the ether or the air, as if it were a luminous or sonorous body, but are experiencing a "chemical sense," due to the chemical action of physical particles—which may themselves be gaseous, liquid, or solid—from the body in question.

There are many puzzling aspects about the sense of smell, and it may be suggested that the obscurity and uncertainty of outline which the facts of this sense present are partly due to the circumstance that it is decadent in man, and suffers from those marks of decadence which show themselves in obscurity and inconstancy in the case of other organs and functions.

The Inadequacy of the Study of Flavours and the Trained Nose

The best psychological observation has hitherto failed to analyse the sensation-qualities of this sense as we have succeeded in doing in the case of the eye, the skin, and the tongue. This is, no doubt, partly due to the fact that we cannot test different parts of the olfactory mucous membrane as we can test the different spots upon the skin or the tip, edges, and back of the tongue. In the nature of the case, we have to apply our stimulus to the whole surface at once. Also, it is difficult to find suitable subjects to study, because individuals in whom this sense is well developed are comparatively rare, and such people as gourmets or wine or tea tasters are not always readily accessible in psychological laboratories.

No doubt a thorough study of the sensory discrimination of such people would add much to our knowledge of the subject. At present the best we can say is that different odours seem to vary in complexity, and that the trained nose can detect certain simpler elements in what seem to the less trained nose to be simple odours, such as the flavour of a sauce, or of a blend of tobacco or tea or coffee or wine. It need hardly be pointed out that the flavour or bouquet of a great many pleasant things for which we thank the sense of taste is readily dependent upon the nose, and taste plays a quite subordinate part in our enjoyment.

as those who are deprived of the sense of smell can attest.

It seems probable that even the degenerate olfactory sense of man includes, at any rate, several more varieties of sensation than his tongue can display. It has been possible to form a classification of scents or odours which appears to reduce them to about eleven groups, the members of any one of which resemble one another more than do the members of any other. Profoundly interesting and difficult problems in what may some day be called psychological chemistry are raised when we try to establish relations between the members of these various groups in terms of chemical composition. We find that, just as most substances built after a special plan and known to the chemist as sugars are sweet, so most of the volatile oils which are derived from turpentine and resemble it in composition have a similar flavour. Thus we speak of ethereal oils, aromatic substances, and so on, which are allied chemically and also allied in the class of olfactory sensation which they induce. This is very conspicuous in the case of the aromatics derived from benzene and the terpenes.

What will be the Effect of Chemical Study on the Sense of Smell?

The future will, no doubt, be able to say far more as to the relation between chemical composition and psychological effect: and when we have the chemistry of these "chemical senses" elucidated from this point of view, it will be possible to construct compounds which will have particular flavours—that is to say, particular actions on the olfactory nervous apparatus, just as it is already possible to construct hypnotics which have a predictable action upon that part of the nervous apparatus which is concerned with sleep.

So much for our account of the "five senses," though we have found that they are many more than five, and though there are several more to consider. It remains for us briefly to consider the æsthetic and ethical questions which are raised by the comparative study of the various senses so far as we have pursued it. We have already stated certain grounds on which the eye and the ear are to be regarded as superior to the other senses. Let us remind ourselves, further, that taste and smell, like the cutaneous senses, are, above all, concerned with our protection rather than with our instruction; they exist for the preservation of the body rather than the illumination of the mind. The chief functions of the nose and tongue are to cause us to avoid or reject things which they find offensive, and which, in fact, are almost invariably found to have noxious properties associated with those which cause these senses to dislike them. But it is the body that they are concerned with, and only with difficulty and rarely can they be made available for higher purposes.

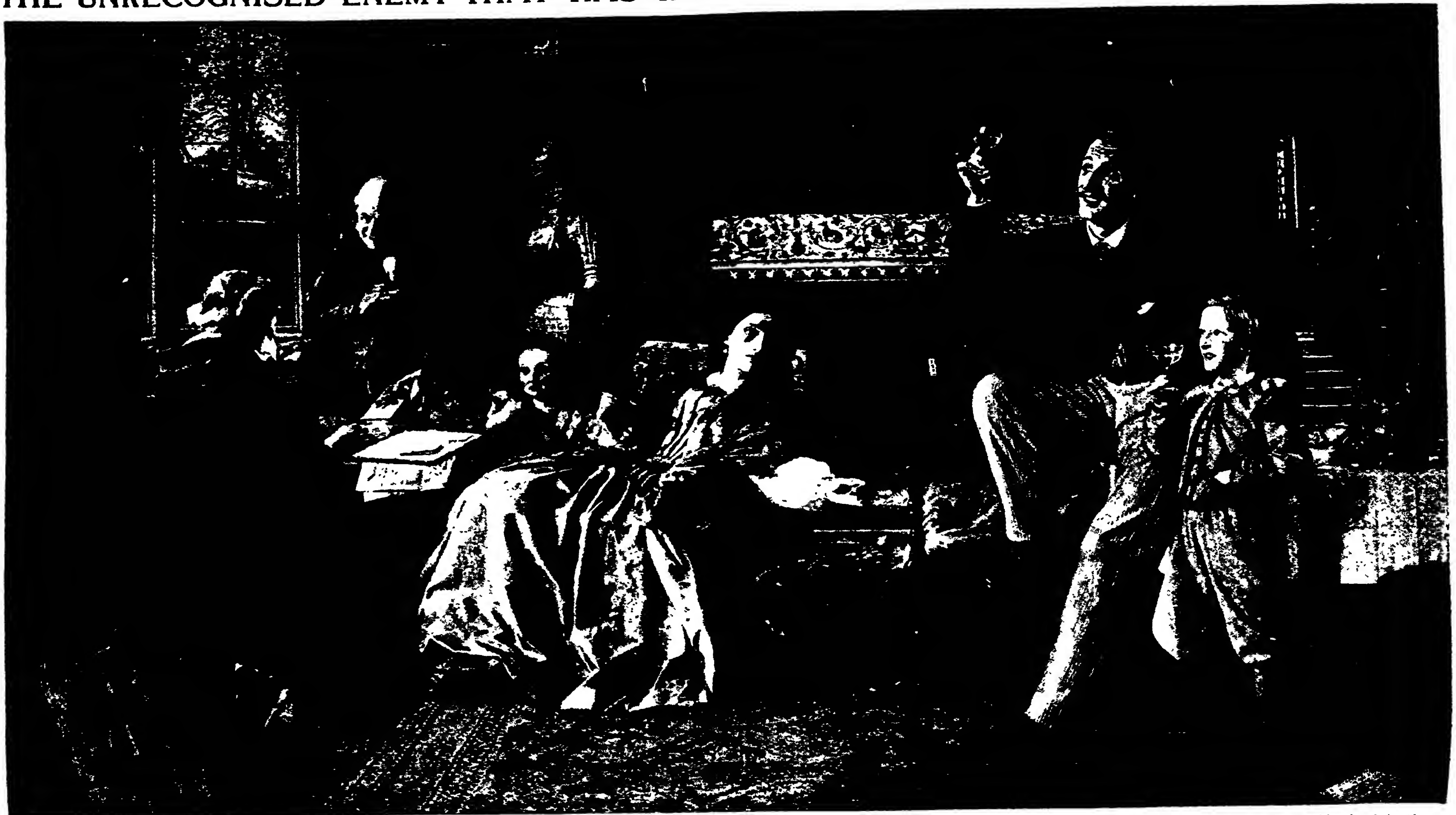
The Senses that Minister to the Body and those that Affect the Spirit

That is why we instinctively feel entitled to apply to pursuits of certain sensations, including those of the "palate" (which is midway between tongue and nose, and stands for the combination of both), the condemnatory word sensual; while we decline to apply the same word to the lover of music or pictures, except when the music or pictures are, as we say, of a sensual kind. The question which determines our judgment is the extent to which the sense which is being gratified leads to the mind through the body, or stops short at the body, and thus never leads to anything more than sensation. The reason why the pleasures of visual and auditory art are regarded as elevating and worthy of admiration and respect is that these senses are the gateways of "Man*soul*" indeed, and excite emotions, which are often noble or ennobling, in the very citadel of our being. If a "chord" of taste, or the successive "chords" of a banquet, could excite emotions of the depth and quality of those excited by the chords of what we call noble music, or the colour-scheme of a noble picture or sunset, then the "culinary art" would rank beside that of Bach or that of Rembrandt.

Looking to the End the Test of Human Tendencies

This is the true and final reply to those who argue that it is just as well to enjoy a good meal as a noble picture or symphony, or even a noble poem. Here, as elsewhere, the everlasting criterion holds—"Look to the end thereof." As Tolstoi showed in his profound and powerful book "What is Art?" we must name and appraise any art, psychologically and morally, in terms not of the mere sensations at the surface of our bodies, but in terms of the emotions it conveys to ourselves. The sensory or sensuous pleasure may be extraordinarily acute in the case of smell, as the result of fine cooking, or even from contact with soft materials. But we place these low in the scale because they lead nowhere; while great art, merely using the senses, can "purge the soul with pity and terror."

THE UNRECOGNISED ENEMY THAT HAS INSIDIOUSLY UNDERMINED AN ANCIENT HOME



"THE LAST DAY IN THE OLD HOME," THE CELEBRATED PICTURE BY ROBERT BRAITHWAITE MARTINEAU, IN THE TATE GALLERY, LONDON

THE DEMAND FOR ALCOHOL

The Difference Between Thirst and a Craving; and the Vicious Circle Set Up by Poisons

KEEPING A BALANCE IN NATURE'S BANK

The influence upon the body of a substance with such various and marked physical and chemical properties as alcohol is, of course, equally various and marked. To study it as completely as our present knowledge permits would be matter for a treatise. But our treatment of it can be simplified by reference to some general principles as to the demand for alcohol; and the most important of these depends upon the nature of thirst.

This is a subject we have already discussed. We have seen that all life is lived in water, that the processes of life inevitably tend to foul this water, that life will therefore poison itself if the water be stagnant, and that thus every living creature requires to have an unceasing stream of water running through its person. Thirst is thus a constant attribute of all living creatures, microbes, mice, and men. This is the proper and original use of the word, but we may extend it as we please, by analogy, to speak of a thirst for music, or, if we will, a smoker's thirst for his after-breakfast pipe. But here we mean a crave, a need, an appetite, a want, a liking; and these may be normal or abnormal, healthy or vicious, but are certainly not the primary need of water which we have already discussed.

And we are to observe that nothing will take the place of water. This is a definite chemical compound, which the body must have. Food will not replace it, nor petrol, nor alcohol. The desire for alcohol may be called a thirst, if the desire for anything liquid is a thirst, but the term as used is grossly misleading, and does mislead nearly everyone.

The fact is that the normal, constant, vital thirst for water and the liking for alcohol are usually confounded—none the less readily because, in many instances, the two are gratified together, in varying proportions. The thirsty cyclist at the wayside inn, drinking a light beer, is chiefly desirous of water to replace what he lost when his muscles and skin were working; and the fact that alcohol is in the beer is not what concerns him. He would not turn up his nose at tea or lemonade or half a dozen oranges, or even a glass of water. He is really thirsty. That same man, in his club, after a day's sedentary work, relieved by occasional doses of alcohol, and again ordering a glass of beer, may now be desiring not the water it contains, as he did the other day, but the alcohol. The same man drinks the same fluid, but the two cases are quite different physiologically, and they lead to quite different ends.

Now, morbid introspection and hypochondria and pulse-counting are by no means to be confounded with intelligent understanding of oneself, by which every man, not a fool, should become his own best physician at forty. And, among other things, it is well to know why one really does or desires things. Thus, to describe what may perhaps be a morbid craving, six months more of which will kill one, as thirst is simply an incitement to suicide. Most sensible people will therefore be grateful for a simple, safe, and absolutely reliable test of thirst, to which, somewhat anticipating, we may add a parallel test for hunger.

As regards the latter, which must be fully discussed later, there may be exceptions in certain kinds of invalidism, but, apart from these, we may say that a man is hungry when he gladly eats dry bread. This answers to the general conception of hunger as desire for *food*—food pure and simple; we offer the tramp who says he is hungry, or the greedy child at table, a piece of bread, which is food, pure and simple, and the test is a sure one. If he wants taste, flavour, stimulation, but is not

hungry, he will, in effect, say of the food you offer him: "Thank you for nothing." This test, as we shall later see, may be applied, on occasion, not merely to tramps and children and suchlike, but even to our noble selves (who, in fact, are rarely hungry, for we take precious good care that we never shall be), and the results are quite surprising.

Now let us apply this idea to thirst. If hunger is desire for food, a hungry person will accept food. If thirst is desire for water, a thirsty person will accept water. In the case of hunger, we noted an exception, for ill people may need food, and even enjoy food, but the sense of hunger is itself ill in them, and such that, as we say, their appetite requires to be tempted. The explanation of this may be that the secretions of the mouth and stomach, necessary to moisten the food and swallow it—secretions which are quickly produced by dry bread in healthy hunger—require some further inducement in the ill person, who therefore cannot eat what is quite nice enough for us. If it left our mouths dry also, we should reject it also.

The Desire to Drink Water the True Test of Thirst

There is no parallel to this in the case of thirst, for water requires no moistening in order to get it swallowed, nor any digestion. Hence the rule is absolute and without exception that the person who—not being too weak to open the mouth—refuses pure water *is not thirsty*. This means, of course, that most of us deceive ourselves every day. We call ourselves thirsty, and order the fluid we desire, but unless, in its absence, we would drink plain water, *we are not thirsty*. We may feel something that corresponds to thirst, and thirst may be a subordinate element in it, but if it rejects water it is not thirst.

A man may call and fancy himself thirsty because he wants a nip at eleven in the morning, and may drink freely at a carouse at night, but that was not thirst in either case. Next morning, however, as he consumes syphon after syphon of soda-water, and the very thought of spirits makes him sick, he will call himself thirsty also, and at last he will be right. In fact, this real thirst which follows the taking of alcohol is a question the answer to which provides us with the key to many features of the action of alcohol on the body.

Ask the chemist what are the relations of alcohol to water, and he replies that, in the proper sense of the word, alcohol is almost the thirstiest thing he knows. Sulphuric acid and some other substances are to be grouped with it in this connection, on account of their remarkable affinity for water. If pure sulphuric acid or absolute alcohol be exposed to water, such as is contained in an ordinary atmosphere, they instantly dilute themselves with it. The process is more than dilution, and has some of the properties of chemical union. So urgent is the affinity. We speak of "absolute alcohol," but so intense is the thirst of this substance that probably chemistry will never be able to extract the last molecule of water from a portion of alcohol so that it shall be really absolute; and what we call absolute alcohol may be anything like 98 or 99 per cent. of alcohol, and the rest irremovable water.

The Affinity of Alcohol for Water a Cause of Thirst

This affinity of alcohol for water is the most important and marked of its physical properties. Hence, if absolute alcohol be applied to a living tissue (say, of the skin or the mouth), which is, of course, mostly composed of water, the alcohol violently abstracts the water in order to satisfy its own thirst, and the result is immediately destructive to the tissue, which has thus been dehydrated, as we say. Alcohol may thus be used, on occasion, as a caustic, but no one can bear to take it in such concentration. This is the key to the "burning taste," and sensation in the stomach, aroused by strong alcoholic solutions. They are simply diluting themselves at the expense of the first tissues which they encounter. Thereafter, the alcohol, somewhat diluted, fortunately, but by no means sufficiently so, enters the blood.

The Insistent Demand of the Blood for Water

The blood is a complex thing, with living elements, but meanwhile we are to look merely at its fluid part. The most remarkable fact about the fluid of the blood is its astonishing degree of constancy of composition. It is for ever supplying certain of its ingredients to the tissues and for ever receiving other ingredients from them, and from the bowel, but it has almost an infinity of devices for always returning to a certain normal composition, in whatever direction that be disturbed. This applies not least to the mere proportion of water in the blood, and thus to its actual physical bulk. If much fluid passes into the blood, much fluid is quickly expelled from it, as anyone may observe. If there is a failure of fluid supply fro

without, the blood will abstract water from the tissues and the bowel, rather than go short—its bulk and proportion of water must be maintained at all costs, for otherwise the brain would have to suffer.

Now, consider the consequences of the introduction of a foreign substance like alcohol into the blood. Of course, it must be got rid of, and as it goes it drags a quantity of water along with it. The result is that the blood is left thirsty.

The Abstraction from the Body by Alcohol of the Water Needed by the Blood

The alcohol which leaves the body is still dragging with it as much water as possible, according to its physical nature. Thus the bulk of milk produced by the nursing mother is always increased by the administration of alcohol, which is partly excreted by this route and carries water along with it; and simple folk—mothers, nurses, some doctors, and others—therefore suppose that the baby is getting more milk.

Further, as we have seen, some of the alcohol is oxidised, yielding new products. If these were carbonic acid and water, plainly thirst would not result; and the fact that thirst does result supports the contention of the writer that the oxidation of alcohol in the body is not complete, and therefore harmless or useful, but is like the oxidation of many other drugs, such as morphine, yielding new substances which are essentially toxic. Thus we now have two explanations, between them quite adequate, for the very remarkable thirst which follows the slaking of what the drinker wrongly calls his thirst. First, it is due to the thirst of alcohol for water, of which as it goes it rapidly deprives the blood and the body, and with which they require to be replenished as soon as possible; and second, it is due to the production of poisonous substances in the body, perhaps from the alcohol itself, and certainly otherwise also, which the body seeks to render harmless by diluting them as far as possible, as in the case of the thirst of fever, and of all forms of intoxication, whether by drugs or microbes, or exertion or otherwise.

Alcohol a Mocker, Causing Afresh the Thirst it Seems to Allay

This, then, is the first we have encountered of the many instances in which alcohol, in the old phrase, is a "mocker." It disguises itself so as to look like what relieves thirst, so as to taste wet, so as to allay what feels like thirst; but so far is it from doing so that, on the contrary, it is overmasteringly thirsty itself, and simply deprives the body of the one thing which relieves thirst, and the loss of which produces thirst—namely, water. From the point of view of the student of physiological chemistry, there is an almost diabolical cunning in the ease and constancy with which poor human nature is thus cheated. For, unless the alcohol be very dilute, every successive drink only increases (after a little while, when the mouth and throat get dry again) the thirst which it professed to relieve, and thus a vicious circle is set up, to which the subtler action of the alcohol itself upon nervous protoplasm contributes.

Surely it must be a contribution to public health that we should call things by their real names, and that we should thus try to rid ourselves of the tyranny of imitations; for the imitations of thirst, the imitations of patriotism, the imitations of religion, are at all times very nearly too much for the life of man. Henceforth let us name them aright; there may be some magic in names after all, when they are the right ones.

The Desire for Alcohol not a Need of the Body, but an Unnatural Craving

We see now that the desire for alcohol is really a craving, an acquired demand of the body. This is the essential and material reason why men drink it. They do also drink alcoholic liquors, as we have seen, in order to relieve thirst, and we have seen what a different aspect that intention wears according to the alcoholic strength of the liquid; secondly, they sometimes drink for the bouquet of the beverage, for the pleasure of the nose and palate (as indeed why should they not, so far as that is concerned?); but thirdly, they drink to satisfy a crave, which they commonly misname as thirst—though the inebriate who is glad to get at methylated spirits is under no delusion as to the nature of his case. If we are to understand the relation of alcohol to personal hygiene, on the individual or the national scale, we must therefore try to understand what a crave really is from the physiological standpoint.

We do well to distinguish craves from needs. The body needs light, air, food, water, and does not acquire the desire for them. Though we habitually avail ourselves of these things, their use is not to be called a habit, nor yet the desire for them a crave. Again, we acquire the habit of liking certain things, particular flavours in our diet, books, music, company, and so

forth, and these are properly to be called habits. The essence of them is that they are acquired, though they may doubtless spring from native tendencies. Habits may be bad as well as good—for instance, the habit of swearing, or making grimaces when one talks, or biting one's nails. The discussion of such habits, good and bad, is very interesting for the psychologist, and has some interest for the hygienist too, of course. But what we are here discussing is something quite different in its nature, though language is so inadequate, and our use of it so careless, that we often speak of obviously excessive drinking as a bad habit. In part it may be so, in that it has become customary or habitual for a man to keep certain company, and do as they do, as, for instance, in the undoubtedly bad habit of "treating," by which many a man's "friends" have sent him to the devil. But all this is subordinate and essentially beside the mark. The so-called habits, bad or not as they may be, of drinking, or smoking, or taking any other drug, are of a wholly distinct nature from other habits properly so-called.

The Difference Between a Habit and a Craving Caused by Drugs

A real habit is a nervous thing; it means that, as we do our best to imagine it, a kind of rut or easy path has been worn in one's nervous system, so that action tends to discharge itself along it, and so becomes habitual. This is a thing acquired with astonishing speed, especially in youth, and, in most cases, discarded or altered with no less speed. When we deal with real habits, not expressions of unalterable instinct, nor drug-cravings, we soon discover how much the so-called force of habit has been overrated, and that such true habits, though they have the standing of a lifetime, can usually be unlearnt, and others substituted, in most instances, within a few days or weeks, especially if one takes certain precautions, or necessity imposes suitable conditions upon us. But all that is because true habit is not a native and permanent and necessary thing, but a mere adaptation or acquirement; and the faculty of making acquirements was not exhausted when that habit was acquired, and can now show itself by unacquiring it, or acquiring its opposite. These assertions will appear to break down at once, whenever what is not really a habit, or "acquired automatism," is mistaken for one.

The case is wholly changed when we study such so-called habits as the desire for any drugs—alcohol, opium, cocaine, trional nicotine, or whatever others, familiar, or yet to be constructed in the laboratories of Germany, we care to imagine. Here we have something which, though doubtless showing itself through the nerves, is not nervous, like a grimace or trick of speech but chemical. Just in proportion as it can be shown to depend *not* on habit, but on certain chemical facts which, by their nature, are beyond the control of the individual—as a true habit normally is *not* do we come to see that calling the drink crave a bad habit is inaccurate, is unjust, is uncharitable, and will certainly lead us to adopt useless instead of useful courses in dealing with the drinker.

The Treatment of Patients who have Fallen Under the Power of a Craving

Our present discussion of the subject is not academic trifling or professional verbiage. It is not even a matter merely for the expert student. It is a matter which directly affects every individual and the nation at large in their relation to any drug-habit so-called. If the thing is really a bad habit, neither more nor less, then we should punish it—the person is a criminal But if it is a chemical necessity, in the chains of which he has bound himself, then he is a patient, and must not be punished but must be treated.

Plainly, this is not a simple matter We began by proving that people do not drink alcohol because they are thirsty For that purpose it is worse than sea-water But now we have to decide why they do drink; and at once we encounter three schools, which may roughly be stated, with reservations, as follows: the Church says the drunkard is a sinner, and prays with and for him; the State says he is a criminal and locks him up; and the doctors say he is a patient, and treat him. Now, does the drunkard really want prayer, gaol, or medicine, or all three?

The Exceptional Position of the Selfish and Vicious Drinker

The question cannot be answered in a word, because neither truth nor error lies wholly with any of these opinions. The fact is familiar to first-hand students of the inebriate that there are different types of drinkers. There is undoubtedly the vicious drinker; and here we may briefly recognise him, and then put him aside, as he concerns us no further. He is usually of strong constitution, often exceptionally so. Certain of the psychological effects of alcohol please him, and so he drinks. He may have

no true crave whatever. He could control himself if he would, but he will not. Observe this description of his psychology; it is what the law, the sum and symbol of our collective wisdom or folly, assumes for every inebriate—that he could control himself if he would, but will not. That is true of the vicious drinker, who is commonly selfish, though he may by no means be physically brutal. On the whole, he does himself singularly little harm, partly because he often is strong to start with, and partly because he has and exercises enough self-control to stop short of destroying himself.

The Vicious Drinker Guilty of a Cruel Criminality

He is, of course, a curse to those with whom he lives, especially women and children; if anyone is a criminal, and should be punished by the law, he is the man. At present the law on this subject is abominably inadequate- lenient to the selfish drunkard, mercilessly cruel to those whom his habit injures. For this is a bad habit, and should be treated and regarded as such. Pity, sympathy, medical skill, all forms of noble things, love and knowledge, are wasted on such a person. What he needs is punishment, and punishment of a harsher kind than public opinion of the present day, which is so pitiless to his children, would tolerate. Probably the number of such cases, relatively to the whole of drunkenness, is quite small.

If we are to understand the greater part of the problem, we must consider the case of the ordinary person, neither a selfish brute on the one hand, nor a pitiable defective on the other hand, who falls a victim to the drink-crave.

The Scientific View of Patients who have Contracted the Drink Craving

Let science by no means sneer at the services of religion, here or elsewhere, but let us clearly understand, once and for all, that the view which calls this man a sinner or a criminal, and has no more to say, is ignorant, uncharitable, and unscientific. Let such a judge dislocate his shoulder by bad luck when motoring, and have an opiate every night for a week in order to soothe his pain and give him sleep, and then observe how he enjoys having no opiate on the eighth night. A crave is a chemical condition of the blood, the essential characteristic of which is that it can most completely and quickly be altered—to the relief of the patient—by a further dose of the chemical substance which produced it. Modern study has thrown much light upon this subject, and has gone far to justify and illustrate the maxim that to know all is to pardon all. The writer must not be understood to assert that what he is about to describe has yet been proved for alcohol, but it has every probability, and may be proved at any time. It has apparently been proved for morphine by the work of Professor Binz, of Bonn, and it has already been referred to in this section.

Briefly, the reader may be reminded that many instances occur in the botanical world of vegetable products, with powerful actions on the animal body, which can be readily altered, by the plant itself, or otherwise, so as to produce another drug which has opposite actions. In hosts of plants such physiological antagonists can be found in varying proportions. The fact goes far to help us in understanding the action of, for instance, such a vegetable product as morphine.

The Patient a Victim of a Circle of Poisonous Effects

What happens appears to be that the drug is changed in the body, as a result of oxidation which destroys it as such, so that a new drug is produced, the action of which is also poisonous, but poisonous in the opposite direction. Nothing can serve so well for its antidote as a further dose of the original drug. But that further dose undergoes the same change, and thus the patient is liable to become the victim of a vicious chemical circle, where every dose that relieves his symptoms will surely lead to their production anew.

To the self-righteous or uninstructed, or to the very large number of excellent people who really suppose that they are sober because they are good and self-controlled, while other people are miserable drunkards because they are bad (and presumably enjoy being miserable)—to such it may appear that the foregoing is entirely too clever by half, and may be dismissed. Such people would know better if they had seen a victim of the craving for opium killed outright in a few days by having his drug not stopped, but rashly and excessively reduced. In such cases the patient dies of palpable poisoning, though nothing but good, simple food and water may be entering his body; and a large dose of opium will remove the toxic symptoms just as diphtheria antitoxin will relieve the symptoms produced by the diphtheria toxin. And yet all these symptoms were due to opium. It is a great step forward to have reached an intelligible explanation of the facts. The patient in such cases does not suffer from a lack of

anything necessary for life. His symptoms are not those of starvation, as if the opium had become a necessary for his nourishment, and he was dying for the lack of it. They are the positive symptoms of an active toxic process; and there is no doubt that those same symptoms would be produced, in degree, in a second person, if he were injected with a small quantity of the blood of the first.

The Terrible Condition of Drug-Poisoned People when Deprived of Their Drug

This conception of the nature of a drug-crave, as being the outward expression of a vicious chemical circle within the body, may be taken, whatever the details of special instances may prove to be, as fairly typical of drug-craves in general, whether common or rare, serious or trifling. It is probably true alike of morphine, alcohol, and nicotine, for instance, though the intensity of the action in these instances varies within considerable limits. The opium-smoker or morphinomaniac, deprived of his pipe or his needle, may forthwith die of acute poisoning, which can scarcely be called opium-poisoning, as opium would have prevented it.

The tobacco-smoker, deprived of his pipe, may show nervous symptoms of some considerable degree, including irritability, irregular pulse, and incapacity to control the attention, but actual delirium will scarcely ensue. The drunkard, similarly deprived, will have a terrible time, and under cer ain conditions may be precipitated into actual delirium tremens, though the exact facts here are not quite easy to determine. But in all these cases the conception is illustrated that a crave is a chemical poisoning which demands specific chemical relief.

The Man who Needs Alcohol to Make Him Fit is Already Poisoned

We now have the key to the familiar argument of the smoker, and the still more familiar argument of the drinker. "What nonsense it is," he says, "for fanatics to spout all their rubbish about alcohol (or tobacco) being a poison, when I know, and millions like me know, from the everyday experience of years, that this so-called poison does me good, soothes me or stimulates me, or both at once, helps all my functions and my work, my digestion and appetite, my temper, my sleep, and everything else! My case, like an infinite number besides, proves that this is not a poison, but a valuable aid to life." This argument is now intelligible to us. It is quite true, absolutely honest; and we have no difficulty in understanding the very natural irritation of the man whose conduct is attacked, and who finds his best friend called a poison. But place him in line with the morphinomaniac, and he will observe that, by his argument, morphine is not a poison either—"which is absurd."

The fallacy of his argument has now received chemical elucidation. The non-drinker has an effective reply: "My dear sir, I quite realise that you need your drug. The fact is that you are a patient, and, being so, require constant medication—rather a pitiable necessity, but there it is. I am sure you have never been drunk in your life, but the truth is that you are a victim of chronic intoxication—by the decomposition products of your last dose of medicine. I quite understand that you need a new dose, and that without it your intoxication—pray pardon me—puts you in a condition of depression, irritability, lack of appetite, inability to concentrate, sleeplessness, and feeble digestion, so that you require a drug in order to reach the level of health which, I confess, I am fortunate enough to enjoy without such assistance."

The Price Paid for Submission to Poisoning Only Known at the End

That is surely a fair retort, but the drinker need not give in yet. It is open to him to reply that, after all, he has attained a balance, that he has effected a special adaptation; and though he cannot deny that he has made for himself a requirement which the non-drinker does not share, still, that requirement can be easily and completely met.

This argument raises the whole problem of adaptation and its costs. The lover of fresh air gets a bad headache in a stuffy theatre, where people who are accustomed to foul air, and prefer it, are unharmed. It looks as if they, with what is surely a bad practice, have the laugh of him whose healthy preference gives him a headache!

The answer of modern physiology appears to be that, in all such cases, we must look to the end thereof. Prolonged inquiry suggests that in the long run the normal habit and mode of life pay best, because they cost least. The body adapts itself, but it pays a price. It learns to survive under the new and peculiar conditions, from what it was not constructed, but it pays a price, either in the average intensity and efficiency of life, or in the actual length of life, or, as usually happens, in both. Nowhere is better illustrated the everlasting maxim of wisdom—look to the end thereof.

But it is to be granted that the argument requires proper statement and careful inquiry. Immediate observation does not

justify it. The drinker or the smoker can not only prove in his own person, day by day, that he is the better for each individual dose of his drug, and is therefore, as would seem, entitled to argue that it is a beneficent drug—forgetting the morphinomaniac, killed for lack of his morphia—but also he can prove, by experiment on himself, that the good results promised if he will stop his "bad habits" do not follow. In point of fact, he feels much worse. This is first-hand evidence; it continues for days, perhaps, and not unnaturally he returns to his pipe or his glass. The writer guides his pen with sympathetic experience of, at any rate, the former case. And even if the renouncer sticks to his guns until the chemical balance of his body has returned to the normal—for no one can deny that not to crave for pipe or glass must be the normal—it is very likely that, while he feels none the worse, he feels none the better.

The Statistics of Disease a Better Guide than Personal Feeling

By no means is this true in every case; the writer has had many scores of letters from those who have followed his advice about alcohol as a public physician, and who proclaim themselves new men or women. But there are probably as many cases, or more, where the self-reformer, not unnaturedly proud of his feat, and expecting some return for what it cost him, finds that he is much as he was. Then why on earth, if he is no better, should he not return to what, he argues, clearly does him no harm, and was certainly enjoyable, when looked at from one side? The answer to this frequently encountered and entirely reasonable argument of the individual is that furnished by the statistics of such diseases as cancer and consumption, and by the records of life-insurance companies over now many decades in Great Britain, the United States of America, and elsewhere.

It is the answer which has been already stated: that the adaptation to any abnormal mode of life costs something, and that this cost shows itself in a shortening of life, and in a marked lowering of its intensity and efficiency and happiness, after a time.

The Power of Resisting Disease Limited by the Use of Alcohol

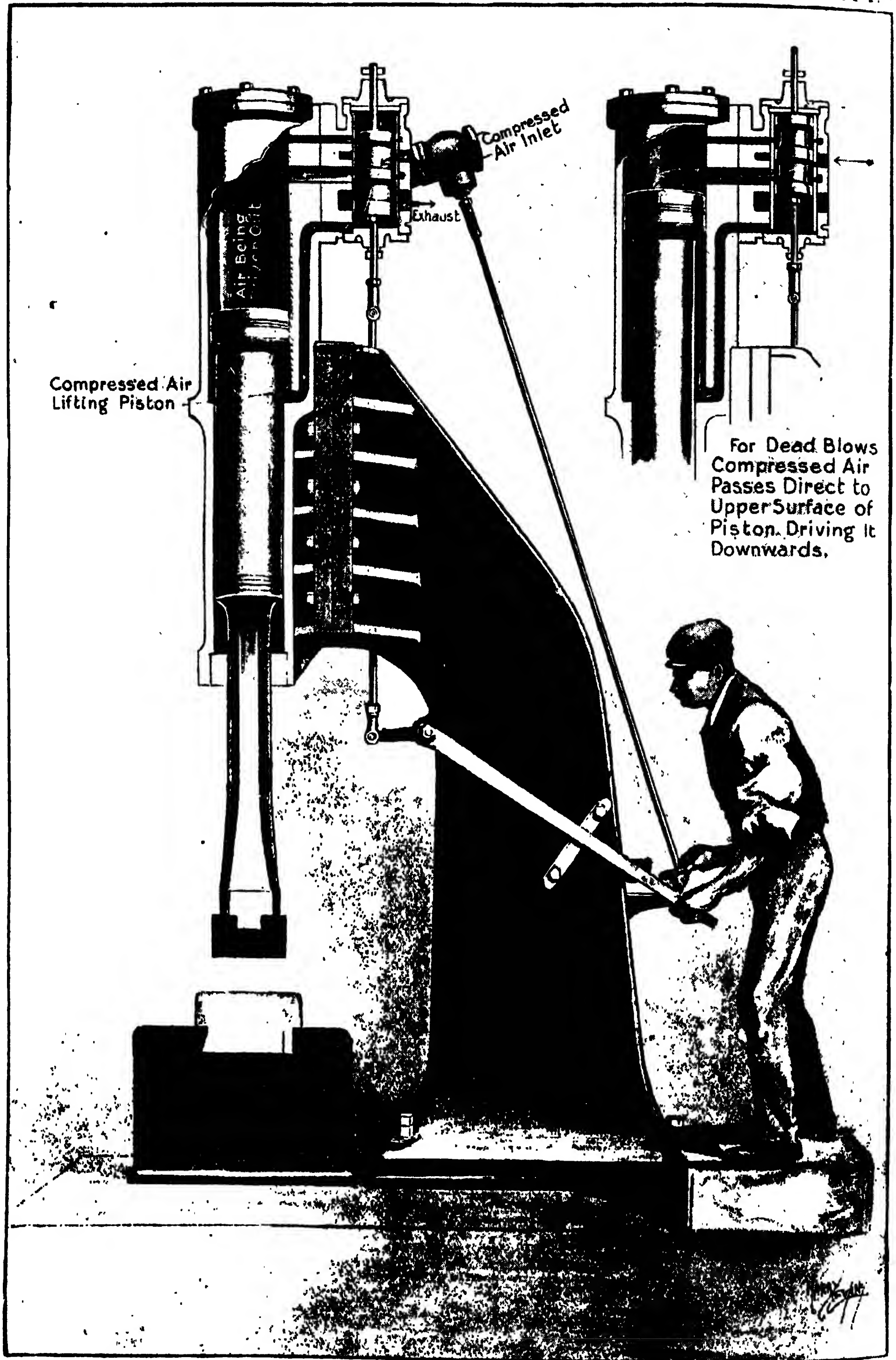
It will be obvious that nothing else can be expected if we consider that the chemical adaptations and reactions to morphine, alcohol, or what not must cost the body; and evidently the state of health that can be attained by these means under these conditions must be a precarious, difficult, and unstable affair, with little margin compared with the health of a person who does require his body to perform these special chemical feats. And so we should expect to find—what we do so constantly find—that when the body is attacked by a new enemy—influenza, consumption, pneumonia, or what not—its balance is far more easily upset, and its resistance far less powerful and rapid, its resources far more limited, in the man who has habitually been plunging so deeply into his physiological resources than in the man who has not. Perhaps both men were healthy, but they kept a very different balance at the bank.

One further point remains for insistence, in regard to what we have learnt as to the general relations between alcohol and the body, before we begin to study its local action. This is that, henceforth, our attitude towards any drinker who is in difficulties of any kind in consequence of his drug must be made far more sympathetic, far less censorious than hitherto. Not merely the feeble-minded inebriate, who is another class apart, and does not concern us in this section, as he is beyond the resources of hygiene, but also the ordinary drinker whose practice is injuring him in any way, financially, socially, physiologically, requires to be looked upon as a doctor looks upon a patient for whom he has been too freely prescribing an opiate that must now be controlled.

The Difficulty of Tiding the Drinker Over Changes in His Bodily Chemistry

The problem before us is not vice, though it may have vicious connections and consequences, or even a vicious or reckless foolish origin; it is chemistry. Let us use all resources available in the way of exhortation or definitely religious exercises, but let us moderate our blaming, and, having begun to understand, let us go on to treat with understanding. If the drinker is to be deprived of what he has come to need, in the singular boomerang-wise fashion we have discussed, we must do our best to replace that need with something harmless. To deprive him of his drug and leave him depressed, uncompanioned, with no interest, no tonic, no suitable diet for his feeble digestion, nothing but nagging or ostentatious approval, no attempt to counteract his toxic state and tide him over the critical change in his bodily chemistry—this is to court failure. But it is the almost universal practice, and will continue to be so until the public receives a little elementary education in the matters which most concern its health and happiness.

HOW THE PNEUMATIC HAMMER WORKS



In the main picture the workman is admitting compressed air through a valve to the under side of the piston for the purpose of raising the hammer ready for the blow. The smaller picture shows the valve open, to admit compressed air direct to the top of the piston to drive it downwards with great force.

THE POWER OF THE AIR

How Air is Compressed by Water and Made to Perform a Thousand Tasks

WONDERFUL USES OF OUR ATMOSPHERE

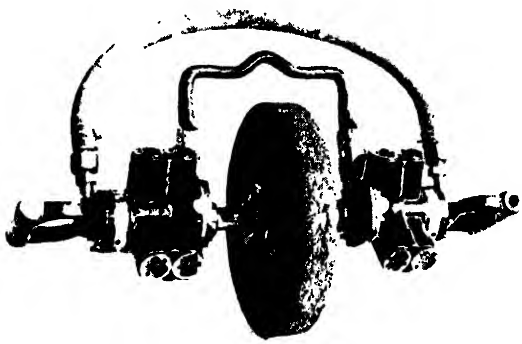
The air we breathe is now made to drive some hundreds of kinds of mechanisms. In many important industries it is much cheaper than steam. For instance, the Cleveland Stone Company, of America, that works the largest sandstone quarry in the world, has recently installed a central air-plant in place of its steam-driven machinery. By this means nearly one-half of the cost of working has at once been saved. The expenses have dropped from £52 a day to £29.

About two hundred and fifty years ago it was generally thought that air was useless as a source of power, because it had no weight. An experiment of Aristotle was supposed to have decided the matter. The Greek philosopher filled a bladder with air, and then carefully weighed it; he also weighed the bladder when it was empty and collapsed. Finding that there was no difference in weight between the inflated skin and the collapsed skin, he concluded that ordinary air was lacking in the chief property of matter. At various times other men made the same experiment, and obtained the same result. So it looked as though the question had been decisively settled. Yet all the time the air of the earth was pressing on the weighing-machines with the remarkable weight of about 14½ lb. to the square inch. That is to say, if the scale of the weighing-machine was a foot long and a foot broad, the column of air resting on it weighed nearly a ton!

Aristotle's experiment was really ridiculous. When the skin of the bladder was being weighed, the same amount of air pressed on the scales as when the filled bladder was used. The only difference was that in one case nearly all the air was outside the collapsed skin, and in the other case a little of it was inside the filled bladder. It is said that Galileo devised a more scientific experiment by weighing a globe that was first filled with ordinary air, and then with compressed air. As the weight was greater in the latter case, the great Italian man of science ought to have drawn the conclusion that air was heavy. He does not, however, seem to have done so; and it was not until the invention of the air-pump by Otto Guericke that the extraordinary power of air was understood. In 1650, Guericke pumped the air out of a large globe of glass, and then weighed the empty globe. After this he refilled the globe with air, and weighed it again. He found that a cubic foot of air in ordinary circumstances weighs about an ounce and a quarter. So air is about 773 times lighter than water. We, however, live at the bottom of an ocean of air, a hundred and more miles deep; and this huge volume of invisible gas presses upon us with the extraordinary weight of a little more than 2116 lb. to the square foot.

Here, then, is an immense source of power that is running to waste. The difficulties of making any large use of it are, however, insuperable. The ordinary suction-pump is the only widely practical machine in which the weight of the earth's atmosphere is turned into work. In this instance, the pressure of the atmosphere on the external surface of the water causes the fluid to rise in the pump with every movement of the piston. For the piston creates a vacuum between its lower side and the water at the bottom of the pump, and into this vacuum the outside pressure of air forces the water. That the pump is worked by the air of the earth is shown by the fact that, no matter how long the stroke of the piston is, the water cannot be raised more than thirty-four feet above its level. The piston may produce a vacuum at thirty-six feet, but the vacuum remains a vacuum. The water will not rise and fill it, simply because the weight of the atmosphere is insufficient to impel it any higher.

The fact is, Nature does not abhor a vacuum except in regard to the pressure of the atmosphere. This pressure can balance a column of water thirty-four feet high, and no more. The limitations of the ordinary pump were an insolvable problem in the age of Shakespeare. Engineers could not understand why they could not lift water as high as they pleased by making a very long cylinder fitted with a tight piston and a very long piston-rod. The explanation is that they were creating vacuums at a height above the power which the atmospheric pressure exerted on water. To lift water higher than thirty-four feet it is necessary to use a forcing-pump. Here the piston strikes the water and drives it into a narrow pipe and impels it to mount. The principle of working is entirely different from that of a suction pump working by atmospheric pressure.



A PORTABLE GRINDING-STONE WORKED BY AIR

Yet the power of air is used in a new way in the very latest of pumping machines. If you fill a tumbler with water to the brim, and dip a straw to the bottom of the glass, and blow through it, the water will overflow, because it is displaced by rising bubbles of air. Such is the extraordinarily simple principle of the air-lift. In place of the tumbler there is a long, upright pipe filled with water; and running down this pipe, and connecting with it at the bottom, is a smaller tube into which compressed air is forced at a high pressure. The top of the air-tube is fixed to an air-compressor; and according to the degree to which the air is compressed, the water rises in the main pipe. The water supply of many towns and villages in various parts of the world is raised into reservoirs by means of air-lift. The air-lift is also used on ships to move the water-ballast from one compartment to another, so as to give the vessel just the trim or inclination desired. In chemical works it raises liquid so corrosive that no other form of lifter is practical. Having no valve or other moving parts to be deranged by sand or dirt, it is a capital draining pump.

Its only defect has been that the compressed air used in forcing up the water could not be recovered and set to work again. But even this economy in working has now been achieved. The new invention is called a return air-pump. In this machine there are two air-pipes running from the air-compressor. A switch automatically reverses the flow of air in such a way that, while the water is being forced out by the air in one pipe, the discharged air from the second pipe is returning to the intake of the compressor. As the returning air enters the compressor, it exerts its force upon the travelling piston, and thus supplies part of the power necessary for compressing the air upon the pressure side. It is reckoned that the return air-pump is one of the most economical forms of power in existence.

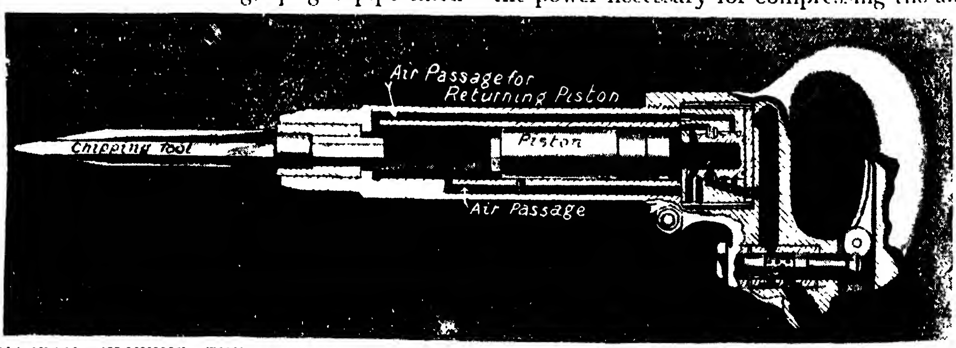


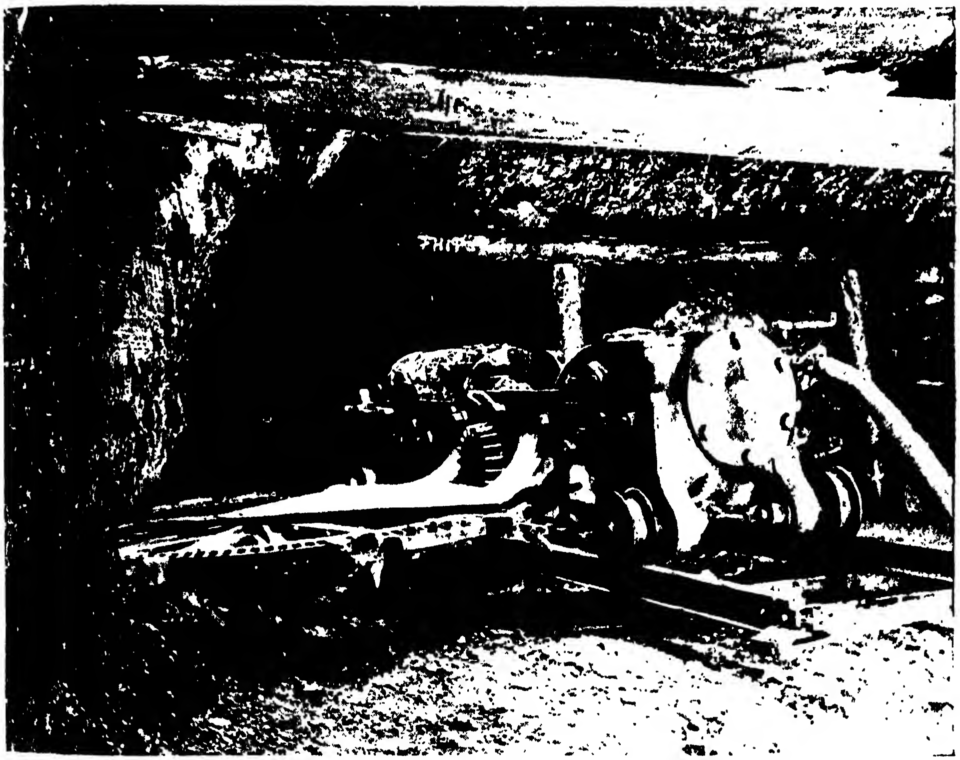
DIAGRAM SHOWING THE PRINCIPLE UPON WHICH A PNEUMATIC CHIPPING HAMMER WORKS

The drawing shows the compressed air rushing into the cylinder to drive forward the piston to strike the chipping tool at the instant after the finger lever has been drawn back

With the exception of the suction-pump and a few other contrivances which are

little more than scientific toys, the atmospheric pressure of air cannot be made to work anything of practical value. But as air has weight, it is easy to increase its weight and force by compressing it. Ordinary air has been compressed to four thousand times the ordinary pressure of the atmosphere. In scientific phrase, it has been compressed to 4000 atmospheres. Its pressure was then more than eight and a half million pounds to the square foot, or, say, about 30,000 tons on a space one yard long by one yard in width. Naturally, there was great danger that the material containing the compressed air would explode under this enormous pressure. It was only achieved in a laboratory experiment. The safe limit of pressure for ordinary work is one-twentieth of this, or 3000 lb. to the square inch.

In the usual air-compressors the power is derived from a steam-engine, or oil, gas, or electric motor. The action is similar to that of a bicycle pump. A piston moves up and down in a cylinder, which has two sets of inlet and discharge valves. One set of both valves is at one end of the cylinder, and another set at the other end. The inlet valve opens inward, and allows ordinary air to enter the cylinder; the discharge valve opens outwards, and allows compressed air to be driven out. On its forward stroke, the piston compresses the air in front of it, and forms a vacuum in the space behind. This vacuum enables the air of the atmosphere to force its way through the inlet valve and fill the space behind the piston. In the meantime, the piston is travelling forward and compressing the air in front of it; and, when a certain pressure is reached, the discharge valve is forced open, and the compressed air speeds along a pipe leading



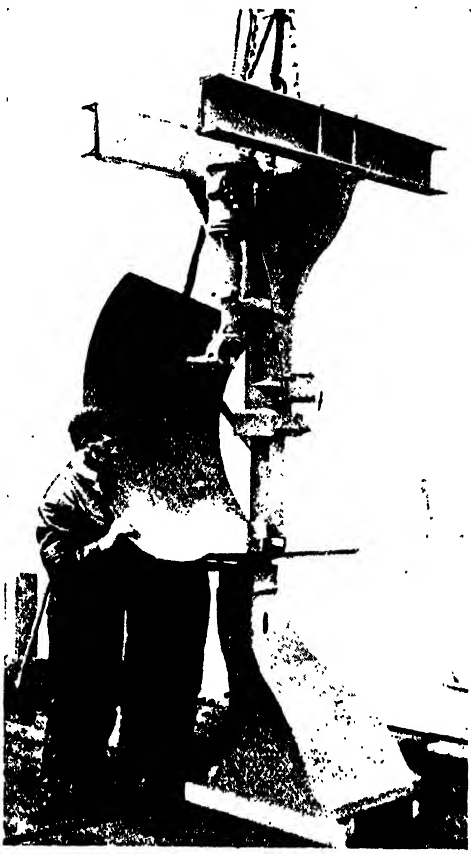
SAFETY MACHINERY IN THE MINES—A CIRCULAR COAL CUTTER REVOLVED BY AIR POWER

to a large reservoir. From this reservoir the compressed air flows into a main distributing pipe. By this time the piston is making its backward stroke and compressing the air that was behind it, and sending that through the other end of the cylinder into the reservoir, and also, of course, creating a vacuum in the rear of its stroke. So the to-and-fro movement goes on in this double-acting air-compressor, and an alternate stream of heavy and powerful air keeps flowing out of the cylinder.

But where a good fall of water is available for transformation into air-power, a more

ingenious, unexpected, and yet simple method is sometimes used. When air in small bubbles is intimately mixed with water, as in a wind-lashed sea, the water breaks into foam, through which the air rises and escapes. But if the mixed air and water are drawn downward by a strong vertical current, and confined on their journey in a pipe, the air is not only prevented from escaping, but it is compressed by the power of the water. The degree of compression depends on the depth and head of the column of falling water. When this has been worked out, it is only necessary to change the direction of flow and make the current run out of an upright pipe along an enclosed level passage. The air-bubbles then rise and collect in a chamber formed above the level passage. The compressed air obtained in this manner is very dry and cool, and more work can be obtained from it than from air compressed by ordinary machinery.

There are several industries in Canada run by water-compressed air. Some cotton mills at Magog, in Quebec, have been worked for nearly twenty years by this method. The water runs down a vertical pipe built of steel plates. The pipe is 3 ft. 8½ in. across at the top, and 128 ft. long. The air is drawn in with the water at the top of the pipe by means of small feed-tubes, and it is compressed while being carried down the shaft, and it collects at the top of an iron receiving-chamber. The difference between the height of the shaft, through which the air and water pour, and the height of the outlet pipe, through which the water escapes free from air, is only 22 ft. Some mines in British Columbia are now worked by compressed air obtained by a plant similar to that of the Magog cotton mills, but much improved in detail. The system has many advantages over the ordinary electric-power water-plant. The construction is very simple, and there is no complicated machinery to get out of order, and naturally the whole thing is cheap to build.



A PNEUMATIC TOOL HAMMERING A COPPER PLATE

On the other hand, air-power cannot at present be used at a very great distance from the compressing source. Moreover, the steel or iron pipes through which it is conveyed to industrial centres are more expensive to construct than the thin copper wires along which electrical power can be sent with little loss for hundreds of miles. Generally speaking, air-power comes between steam-power and electric-power in the matter of transmission capabilities. As is well known, it is extremely difficult to convey steam from a boiler to a distant working point without serious loss of efficiency. For the steam grows cold on its journey, and loses much of its force when it arrives at the end of a long pipe, where a piston is waiting to work by its impulse. The same thing happens to a less degree with ordinary air-power.

When air is compressed by means of a piston working in a cylinder, considerable heat is generated. Everybody who has used a bicycle-pump has felt the metal grow warm as he pumped the air into the tyre. The warmth comes from the crowding, jostling molecules of air brought together by the high pressure. The heat represents a part of the work done on the air, and a part of the work which the air is ready at the moment to give back in expansive force. So when compressed air loses its heat in travelling down a long pipe it loses some of its efficiency. For this reason it is highly desirable to manufacture compressed air in a cool condition. For th[illegible]

it has no heat to lose when it is being distributed, and it therefore arrives at the end of its journey with a higher working power. Various devices have been tried to keep the air cool while it is being compressed by machinery.

The best results with regard to cooling were obtained by injecting a spray of cold water into the air-cylinder. This, however, entailed very serious inconveniences in other directions; and at the present time the simple method of surrounding the compressor with a water-jacket is often used. In the more complicated machines, the work of compression is done in three or more stages. There are three compressing cylinders. In the first the air is subjected to a low pressure. It then flows through a cooler, and is compressed to a higher degree in the second cylinder. Again it passes through a cooler, and receives in the last cylinder its final degree of compression.

Whatever method is used, the air flows into the reservoir with a certain amount of heat. This it gives up on its journey through the pipes, losing some of its power in so doing. Little expense, however, is incurred in reheating the air on its way to its working point. All that is necessary is a stove or oven, through which the air-pipe is run. Let us imagine that an engineer is sending air to drive a gang of saws a mile away from the compressing plant. He will soon notice that the exhaust-pipe becomes very cold; and if the compressed air is not well dried when it is produced, its moisture will now be deposited, not merely as water but as frost, to check the machinery. This is because air, like steam, falls in temperature as it expands at work. The fall measures the heat equivalent of the labour performed. But for the chill which the engineer observes he has a simple remedy. He surrounds the air-pipe, as it enters the machinery, with a small heater, fed with coke, coal, or oil. All the frost vanishes, and the air acquires a new elasticity which makes it very much more effective than it was before. By no other means can so much work be won from fuel as by this device. In some cases a heater has yielded $1\frac{1}{4}$ horse-power for an hour in return for each pound of coal it has burnt.

AIR-DRIVEN ROCK DRILLS AT WORK ON THE PANAMA CANAL CUTTING

It was when the tunnel was being driven through Mont Cenis in 1861 that the power of compressed air was first made use of in a large way. It was found that progress was too slow in drilling the rock away by hand labour to make blasting-holes for the

explosive used in excavating the tunnel. Only $1\frac{1}{2}$ feet of rock was removed in a day. At this rate it would have taken forty years to drive the first connecting link through the Alps between the railway systems of France and Italy. So the engineer at last fitted an air-compressing plant to a waterfall, and carried the air-power along a pipe to a machine drill. By this means $4\frac{3}{4}$ feet of rock were removed every day; and by combining the pneumatic driller with a high explosive the tunnel was at last driven through the granite at the extraordinary speed of six feet a day. Naturally, this remarkable achievement of the air-drill excited great interest in the new power throughout the civilised world, and the pneumatic tool has now become a very important instrument in a great variety of industries.

In coal-mining, tunnelling, and quarrying, compressed air has conquered steam, and in many cases it has proved superior to electric power. Especially in coal-mines is air-power valuable. It can be used with perfect safety, since it does not cause sparks or set light to anything. Moreover, it is extremely useful in underground working after it has performed its work. For when it is liberated from the pneumatic tool it forms a supply of fresh air, and helps to ventilate the mine. One coal-cutter driven by compressed air weighs only ten pounds, and yet delivers two hundred and fifty blows a minute. It consists of a cylinder, in which is fixed a piston with a piston-rod projecting through the end. The outer point of the piston-rod holds the steel cutter. The cylinder is attached by a strong piece of hose to the air-main, and an automatic valve admits the air first at the top and then at the bottom of the cylinder. This gives a forward and backward movement to the piston-rod and cutter; and the little machine holes through the bottom of the coal seam, making as little slack as a hand-pick skilfully wielded.

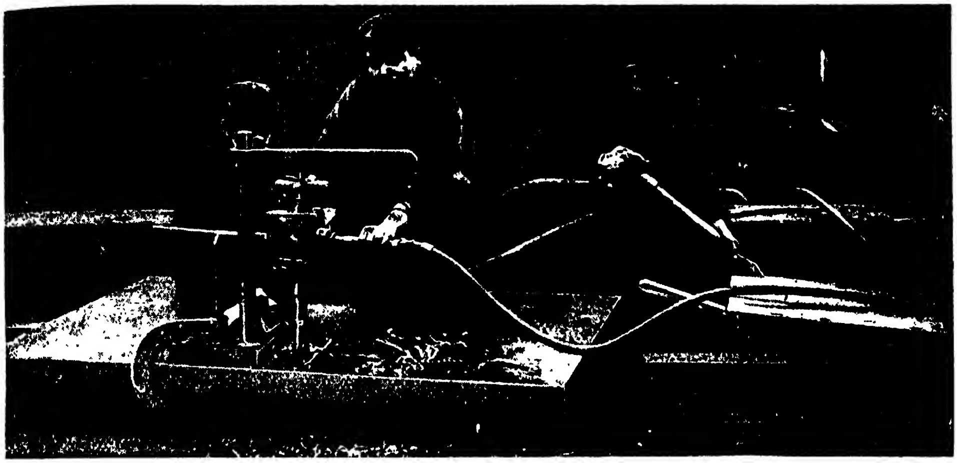

A SCULPTOR CARVING WITH AN AIR-DRIVEN CHISEL

Another pneumatic tool, largely used in mines, takes the form of a disc with detachable chisels or teeth fixed to its edge. It is, in effect, a circular saw. This turns round by air-power, and at the same time travels forward, making a wide saw-cut, either at the bottom of the seam or in the under-clay beneath it. When the cut is long enough and deep enough, the mass of coal either falls down by its own weight or it is blasted down with explosives.

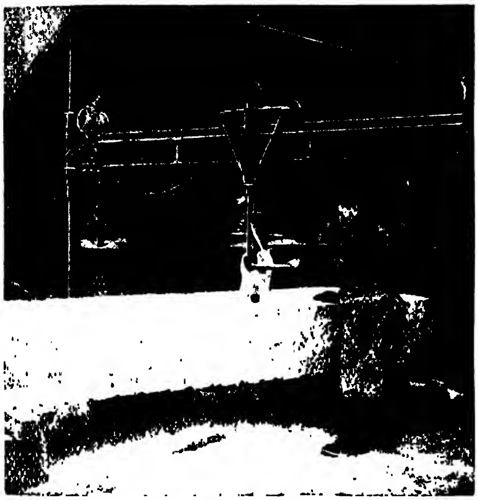
Other pneumatic tools, in great diversity, now perform most of the hard work in mining, tunnelling, and quarrying. Asking for intelligent guidance instead of muscular drudgery, they have transformed a vast army of workmen from hack labourers, with toil-dulled minds, into alert and ambitious mechanics. When all is said and considered, there is nothing like the wonderful machinery used in some great modern industries for enfranchising the mind of a skilful worker. On the one hand, it calls out his intelligence; and, on the other hand, it frees him from bodily toil of a mind-numbing sort. This is particularly the case where the machine-tool requires judgment and knowledge in handling, saving the worker from muscular effort, but demanding intelligent direction.

It may be questioned whether popular school education has done as much to elicit the intellectual ambitions of the working people as the stimulus of mind that many of them have received while learning to direct the steam-driven lathes and hydraulic tools and air-tools that are widely and continually displacing hand labour. A first-rate piece of machinery under one's personal guidance is often more interesting and more provocative of ideas than a literary masterpiece. It is a striking and actual embodiment of human genius in one of its highest powers—its power over the resources of Nature, the

THE ATMOSPHERE AS A SAMSON AT WORK

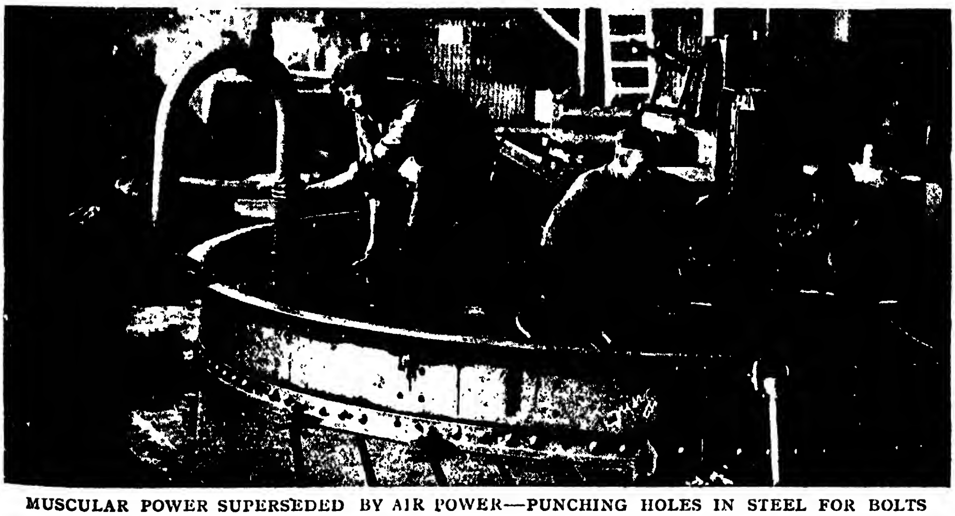


CHISELLING STEEL GIRDERS WITH A TOOL OF HARDER STEEL



SURFACING A BLOCK OF GRANITE

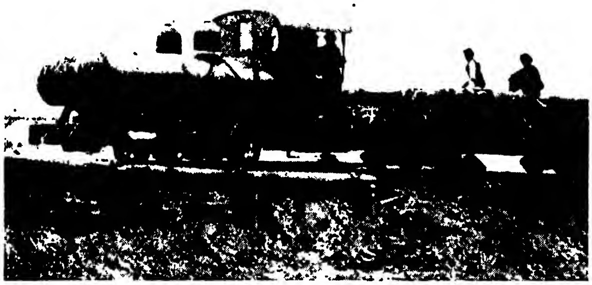
DRILLING INTO HARD ROCK



MUSCULAR POWER SUPERSEDED BY AIR POWER—PUNCHING HOLES IN STEEL FOR BOLTS

power that is establishing that kingdom of man that Francis Bacon, three hundred years ago, visioned and glorified.

The increasing use of air-power is really as wonderful as the increasing use of electricity. To take the invisible and apparently weightless and mysterious atmosphere, and ram it in iron boxes, and conduct it along pipes, and set it to perform hundreds of different tasks, is even a stranger achievement than harnessing the visible lightning of heaven. It would take three or four pages of POPULAR SCIENCE merely to catalogue the diverse uses to which the air we breathe is now put. Air-drills are employed in mines, wells, tunnels, and rock foundations. At will the new power wields a hammer instead of a drill. Air-riveters build ships and bridges, as well as fasten together the plates of boilers and fire-boxes. With a little variation in their form we have a tool that caulks, or stops up the seams of boilers, tanks, and ships. Air-hammers, light and strong, have revolutionised the art of cutting and carving stone, for they enable the force of the stroke to be regulated by a touch of the finger.



A LOCOMOTIVE DRIVEN BY COMPRESSED AIR

There are two kinds of pneumatic hammers. In the valveless hammer the piston acts as a valve, opening and shutting the holes through which the compressed air enters and departs. In the valve hammer the air is admitted and sent out by a separate moving valve. Valveless hammers have a short stroke, repeated two hundred and fifty times a minute, and used in chipping and in closing seams. Valve hammers seldom make more than thirty-five strokes a minute, but each stroke is long and forcible. These are the hammers used in riveting.

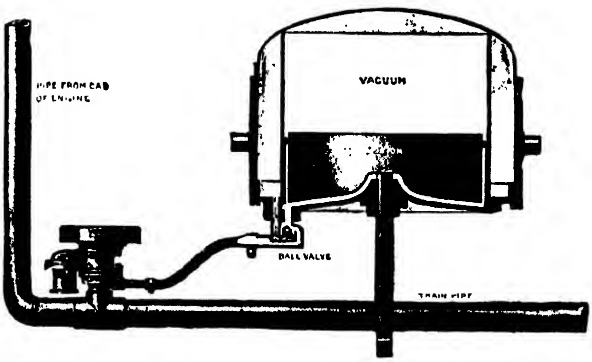


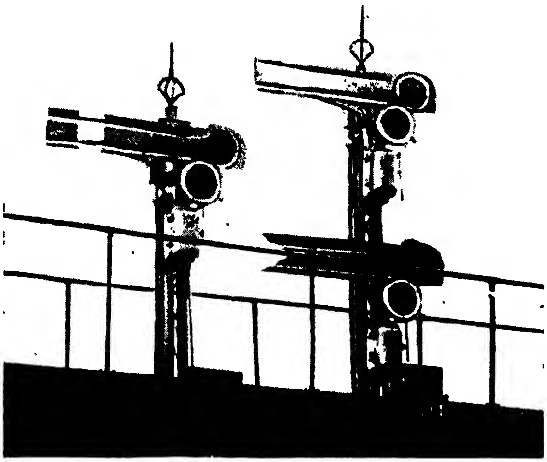
DIAGRAM OF THE RAILWAY VACUUM-BOX
When a train starts, the engine exhausts the air from a pipe running the whole length of the train, and connected with vacuum-boxes. These boxes contain pistons attached to the brakes, and when air is admitted to the pipe, as by pulling a communication cord, it enters each box and forces up a piston that automatically applies the brake.

The idea of the heavy air-hammer is said to have been taken from a tiny tool employed by some dentists for filling teeth with gold. The dentists used a little pneumatic rammer, attached to a small flexible tube filled with compressed air. The rammer simply consisted of a small cylinder in which a piston-rod worked up and down, the end of the rod forming a ram for beating gold into a hollow tooth. Now an enlarged form of the air-driven piston-rod is employed as a rammer for foundry beds or roads, and pavements and railway tracks. In foundries a moulder is furnished with a small sand-shifter vibrated by compressed air, which enables him to do the work of five men. Hoists of all sizes are now worked by compressed air. In every case the mechanism is so simple that it stands the roughest usage, and when any repair is necessary it is easily and cheaply effected.

Many boring tools of a light and convenient form are now worked by air-power, for it is as easy to get a rotary movement with the new power as it is to obtain an up-and-down action. There are very few parts to get out of order, and as these are usually made in standard sizes a worn-out part can quickly be replaced at little cost. Generally speaking, a pneumatic tool requires only two holes—one for the air to enter, and one for it to depart when it has given a push to the working part of the machine. It is the principle of the steam engine reduced to the simplest and most

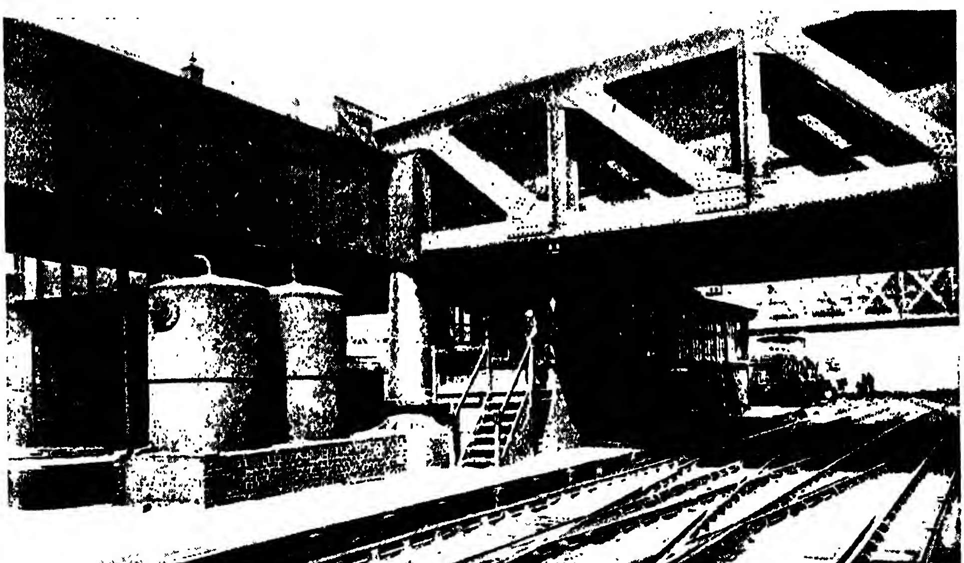
straightforward action. There is no boiler, no condenser, and, as a rule, no cranks and other intricate pieces of mechanism.

No doubt the simple pneumatic tool may, in the course of time, develop into some complicated structure of machinery. Already compressed air is being used in conjunction with electric power to drive a colossal planing-machine weighing 422½ tons—more than the weight of half a dozen ordinary locomotive engines. The bed of the machine is sixty feet long and thirteen feet wide, and it has taken a hundred and thirty tons of metal to make it. The table, without its load, weighs nearly 70 tons. And as it was calculated that the reversal of the direction of such an enormous mass could not be accomplished by ordinary methods, pneumatic power is employed. In fact, compressed air and electricity work all the complicated trains of mechanism for raising, traversing, and feeding the cutting-tools. The movement of a handle regulates the length of the stroke to suit the size of the object which has to be planed; and in spite of the gigantic scale of the machine, adjustment is possible to a very small fraction of an inch.



RAILWAY SIGNALS WORKED BY COMPRESSED AIR
The compressed air is released from the boxes, to be seen below each signal, through a valve operated by an electric current.

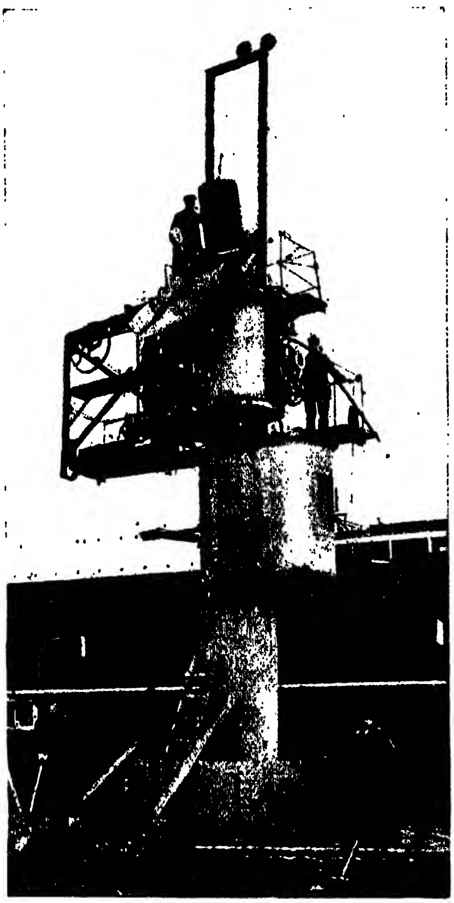
Insignificant in comparison with this colossal tool is the little electric air-drill which has recently been introduced. Yet the small drill embodies an idea which may have a far-spreading effect on every kind of portable labour-saving tools. It has long been recognised that, as a medium for the transmission of power, electricity possesses many advantages over compressed air. It is still cheaper to generate, and it will always remain easier to transmit; and the cost of an electrical installation is considerably lower than that of a compressed-air plant with its expensive pipe-line. Yet electricity, in spite of all its advantages, has never come into general use as a medium of power-transmission in mines and quarries. For there are such grave mechanical difficulties



A COMPRESSED AIR RESERVOIR AND A VACUUM TANK AT LIVERPOOL STREET STATION, LONDON

in the way that air remains the supreme motive power for excavation, and for the working of powerful and yet portable tools of various kinds.

The new invention combines the advantages possessed by electricity with the superiority of compressed air. The air-drill is exactly what its name implies—an air-drill worked by electricity. But it is not an electric drill in any sense of the word, for the electric power is not applied to the working part of the machine. The drill consists of two separate portions—a compressor and an air-drill. The compressor consists of a little electric motor encased in a dustproof casing, the whole being mounted on a steel carriage which can run on rails, or simply roll on the ground. The drill closely resembles the ordinary air rock-drill, but it is free from all complications. There is no valve or valve chest, no valve motion or buffers. It is a plain cylinder with a piston on it, mounted on a column or tripod. This drill differs from all other drills worked by electricity in the way in which electrical energy is transformed into mechanical energy. Compressed air, unbreakable and unwearable, takes the place of the mechanical connections hitherto used between the rotary movement of a motor and the to-and-fro action of a piston.



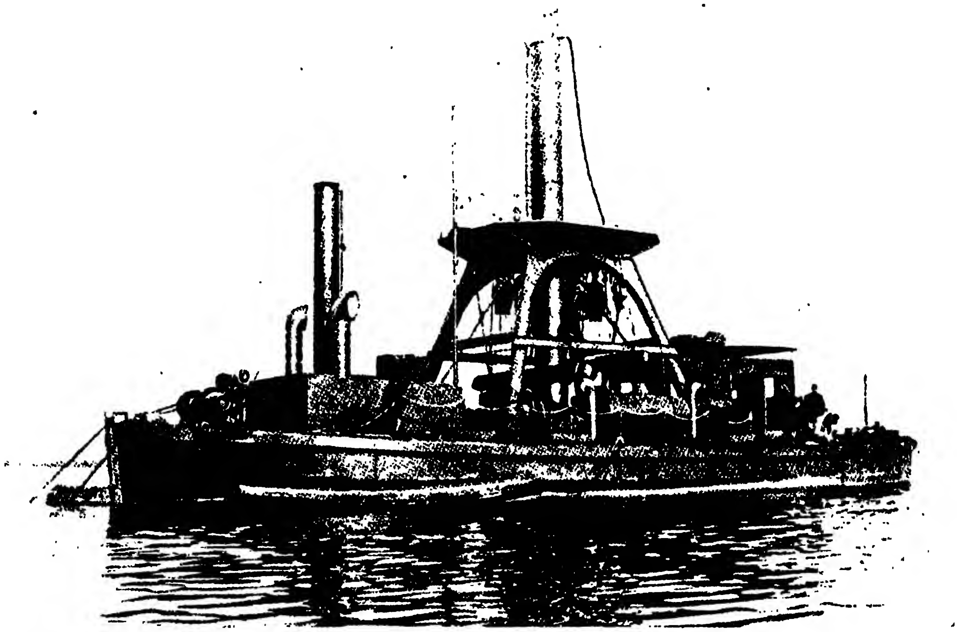
AIR-LOCK FOR UNDER-WATER WORKERS
This air-lock forms the means of access to caissons in which divers work on foundations of bridges and docks. The upper part is for the removal of excavated material, and the lower is divided into two compartments, through which the men enter and leave, adjusting the air-pressure accordingly.

Impulses of air, under a constant pressure of thirty to forty pounds, are transmitted to the drill from the compressor pistons through two short lengths of hose, each leading to one side of the drill-piston, but so connected as to leave a protecting air-cushion at each end. Thus an impulse from one compressor cylinder throws the drill forward, and the impulse from the other cylinder draws it back. The air is not released or exhausted, but is used intensively over and over again. Moreover, as the air expands in the cylinder after compression, it cools the parts, so that no water-jacket is required. The full significance of the new invention can be brought out in a sentence. Only five horse-power is needed to drive the electric air drill, while an ordinary compressed air drill of equal capacity requires from fifteen to twenty horse-power to work the compressing machinery. In other words, the new tool does from three to four times the amount of work of the old tool. The principle of the electric air-drill is esteemed, by some men of high authority, to be the most important advance made in the economical application of air-power to modern industrial purposes.

Compressed air may be said to have been first used by the famous astronomer Dr. Edmund Halley, whose name is for ever connected with the movements of comets. He opened up the work of actually exploring the higher levels of the ocean bed by using the pressure of air to keep the water out of a diving-bell. When the pressure of the water over-balanced that of the ordinary atmosphere in the bell, it was necessary to pump more air into the sinking bell so as to press the water downward. The modern form of diving-bell, known as a caisson was invented by Lord Dundonald in 18[illegible], and first used in France in 1838. It consists of two parts—a small chamber called an air-lock, and a large pressure chamber known as the working chamber. A wall with a door separates the air-lock and the working chamber. On entering the air-lock, a workman opens a valve controlling the pipe connection with the

working chamber. The compressed air then flows into the air-lock and enables the workman to open the inner door. This he could not do when the air-lock was filled with ordinary air, as the force of the compressed air in the working chamber kept the door, which only opened downward, practically locked But when the pressure of air in the two chambers is made equal, the door opens easily.

In the working chamber of the caisson the air is often compressed to as much as the men can stand. It is so dense that it drives the water away, in much the same manner as a hard, solid substance would do. the water out by an enormous force of compressed air contained in two steel casings filled with concrete; but no human being can stand the pressure of the air. A few years ago men who worked in ordinary compressed air were liable to a very painful disease, similar to diver's palsy; but some experiments on behalf of the Admiralty have shown that it is easy to avoid the distressing and dangerous effects of breathing compressed air. All that is necessary is to decompress a workman, by slowly changing the pressure of the atmosphere he is breathing, instead of bringing him abruptly from the compressed-air room into ordinary light air.



AIR-COMPRESSION PLANT AFLOAT—A VESSEL THAT LAYS MOORINGS FOR BATTLESHIPS
This barge carries a diving-bell, which is lowered through a well. The bell is surmounted by a steel shaft, through which the divers descend to the bell, and electric light cables and telephone wires are run. The vessel carries air-compressors for supplying air to the bell and for working pneumatic tools.

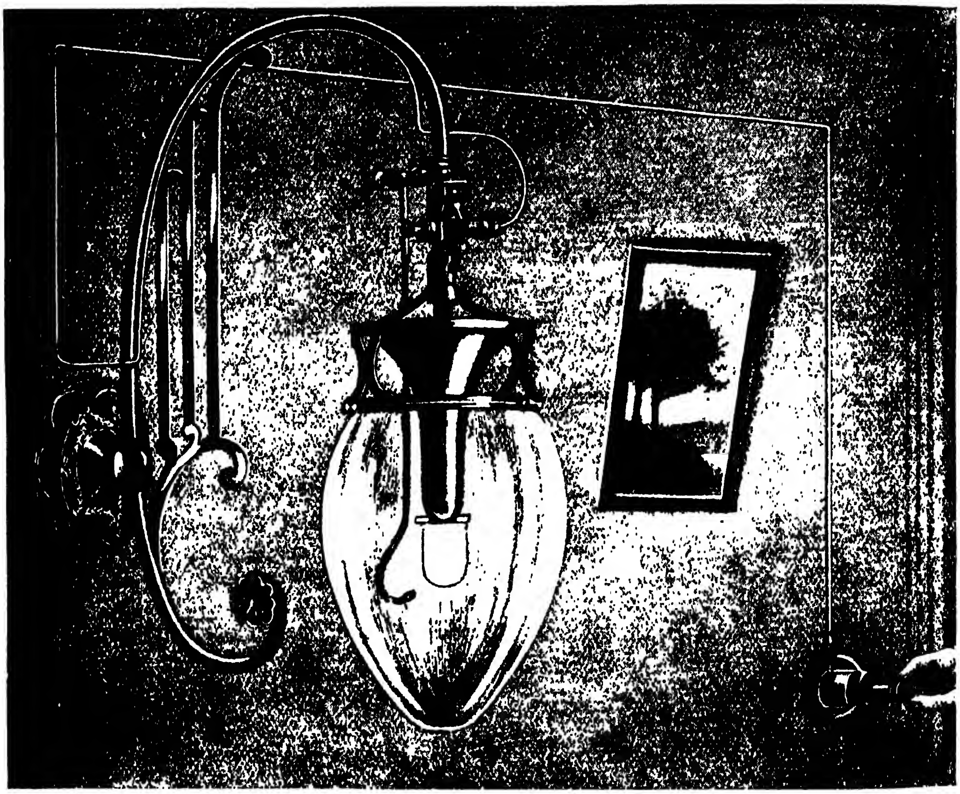
Very often the caisson is at the bottom of the river, and the men in the working chamber are busy digging out the soil in which the pier of some huge bridge will rest. Yet, owing to the force of the compressed air, the part of the river bed that forms the floor of the working chamber is quite dry. All the water is pressed away by the dense and heavy air that is pumped down to the bottom of the caisson. Of course, the deeper the caisson is in the water, the more compressed must be the air in the working chamber to balance the swinging weight of the sea or river. So there comes a depth at which it is possible still to keep

It is compressed air which has made possible the remarkable salvage work of the modern diver. When a diver is working at a great depth, the air that is sent down to him to breathe has to be compressed to a considerable extent. Moreover, he needs compressed air to do his work. His own strength is sadly diminished by the heavy weight of the water around him, but by using a pneumatic tool he is able to rip open great ships built of iron and steel almost as easily as a man on land saws through wood. Mankind has won but little way into the under-world of the ocean, but without compressed air we

should have advanced no farther into the mysterious kingdom of the sea than the pearl-divers reached by human endurance two thousand years ago.

It is also by compressed air that the high speed of the modern railway train is safely maintained. Until the air-brake was invented, railway travelling was dangerous. Now, however, there is a reservoir of compressed air beneath each carriage of a passenger train. The force of this air prevents a powerful brake from acting on the wheels. Any diminution of the air pressure results in the brake coming into action. So any kind of accident that separates a carriage from the train, and breaks the air-pipe running from the engine through all the cars, lets the compressed air escape and so brings the powerful brake into play. In working the air-brake, the compressed air is made on the locomotive and sent through a pipe to a series of reservoirs beneath every carriage. Being practically instantaneous in action, the air-brake enables a long train to be controlled with exquisite and precise gradations. A touch of the finger is sufficient to alter the pressure in the train-pipe and manage the force with which the brake is applied. Invented by Mr. George Westinghouse, of Pittsburg, the air-brake has done more for safe and quick railway travel than any other device applicable to train traffic.

In some mines, compressed air is used instead of steam to drive locomotives. Along the track are charging stations where the train stops and takes in a new supply of compressed air, whenever its storage tank is becoming empty. Usually the air is compressed above the mine, and sent down by a long pipe-line. This makes the air-locomotive more expensive to work than an ordinary train, but the danger of explosion is avoided; and in dry, dusty and heavily timbered mines, or in mines in which fire-damp abounds, the air-locomotive proves in the end cheaper than steam or electric traction. As is

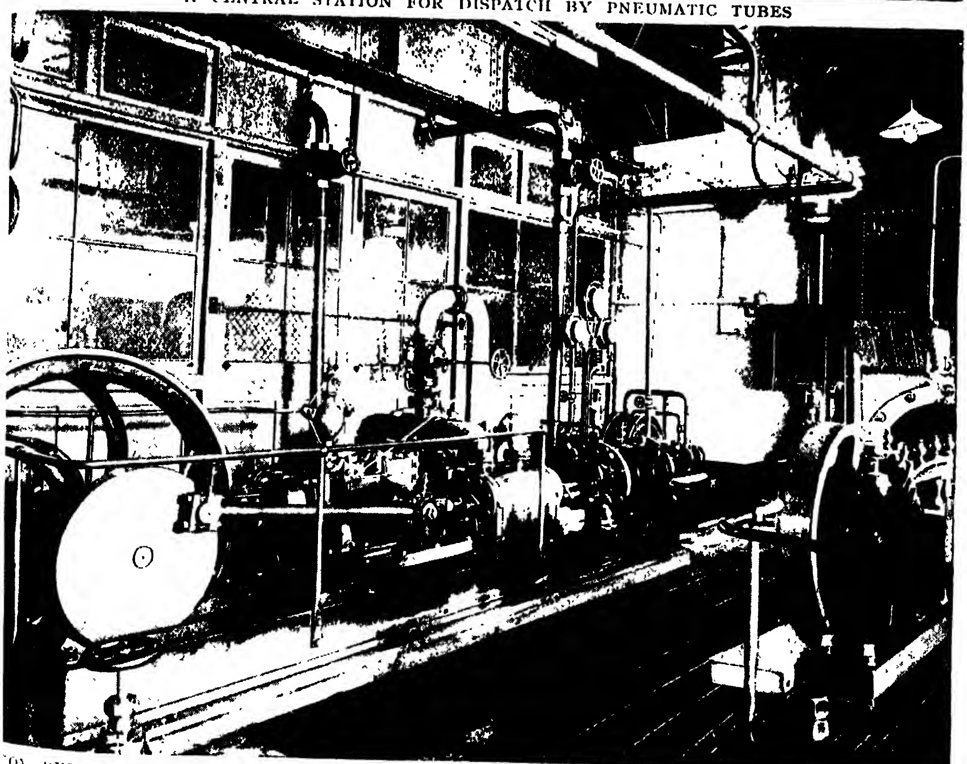


HOW AIR TURNS THE GAS ON AND OFF

This diagram shows the working of a pneumatic gas-switch. When the knob on the wall is pulled out, air is drawn down the tube and sucks inwards a piston at the other end. This piston draws over to the right a small lever, which turns on the gas to be ignited by a by-pass. Pressing in the knob forces back the air, the piston, and the lever to their original positions, shown in the dotted lines, thus cutting off the gas.

PLANT FOR WORKING MESSAGE-TUBES

A CENTRAL STATION FOR DISPATCH BY PNEUMATIC TUBES



COMPRESSOR AND VACUUM PUMP PLANT THAT WORKS PNEUMATIC TUBES HALF A MILE AWAY

The photographs on these pages are by courtesy of The British Pneumatic Tool Co., Reid Bros., Ltd., Siebe, Gorman & Co., The Pneumatic Gas Switch Co., W. F. Garforth, Esq., and others.

known, there is another method of using compressed air for driving a carriage, but hitherto it has been used only on a small scale. In this case the vehicle is blown along a tube by means of compressed air.

Employed chiefly in the postal service of the great cities of the civilised world, the pneumatic mail rivals the telegraph, wherever it has been made generally available. In Paris, indeed, the pneumatic tube has been found to be much cheaper and quite as quick as the telegraph; and it has the additional advantage that all messages are transmtited in the handwriting of the sender. He buys at the post-office a *petit bleu*, which is a very thin letter-card, and writes on it, and posts it in a special box. The card is placed in a carrier, made of indiarubber covered with felt. One end of the carrier fits the tube so nicely that it moves along it without allowing any air to escape. So the carrier is blown down the tube to the exchange, and there dispatched down another tube to the office most conveniently situated for delivery.

A DUST PROBLEM SOLVED--THE MODERN VACUUM CLEANER IN THE HOME

Our own Post Office has not been so enterprising as the Paris postal authorities. Though there are in London forty miles of pneumatic tubes, worked by six large engines, our Postmaster-General is now in favour of building small tubes for electric trains which will carry letters from the district offices to the central office. At present the most remarkable system of pneumatic dispatch is the Batcheller system. It is an American invention, being a development of a pneumatic tube built in Philadelphia. In the new Batcheller system a loaded steel carrier, weighing seventy pounds, travels with a very high momentum through a large tube. It is used for sending parcels, and it is reckoned that it would diminish the street traffic of a large city by doing away with delivery carts and vans, leaving only furniture, pianos, and other heavy goods to be dealt with by a supplementary motor service. Thirty out of every hundred vehicles in the crowded thoroughfares of London would not be needed if there were an efficient and widespread pneumatic parcel delivery. We are much behind American cities in the handling of letters and parcels; and our backwardness seems due to the fact that we have not taken a very active part in developing the pneumatic mail.

It is easy to locate a fault in a pneumatic tube. A blank cartridge is fired from a pistol at the open end of the tube. The sound travels along the passage and strikes against the carrier blocking the way, and then comes back in an echo. By measuring the interval of time between firing the pistol and hearing the echo, it is easy to estimate at what place the tube is choked. For the velocity of sound in air is a known factor; and by finding how long it takes for the noise of the pistol-shot to travel to the obstruction and return, the distance that the noise has travelled can easily be ascertained. Some time ago a breakdown occurred on the Philadelphia tube-line, and Mr. Batcheller used the timed pistol-shot with great success. For a street excavation, made on the rough measurements obtained by the timing apparatus, came within a few feet of the actual break in the pipe, which had been caused by a subsidence of the soil. The carriers themselves were found almost at the point where the workmen were told to begin digging. This was the first time that the timed pistol-shot, invented by M. Bontemps, of Paris, was tried abroad. Its success was remarkable.

Air-power is likely to be applied in hundreds of ways as yet undreamt of. Who

would have thought that the atomiser that is found on many a lady's toilet-table could be developed into a painting-machine! The atomiser consists of a rubber bulb connected to a scent-bottle with a spray. When the bulb is sharply squeezed there is created a little blast of air which breaks a drop of liquid perfume into a fine rain. By magnifying this simple apparatus there has been produced a mechanical painter that covers railway carriages and buildings with paint with a speed and a skill far beyond human hands. Driven with great force, the paint penetrates further into the material than a man could get it, and it reaches crannies and crevices that evade the most skilful brush.

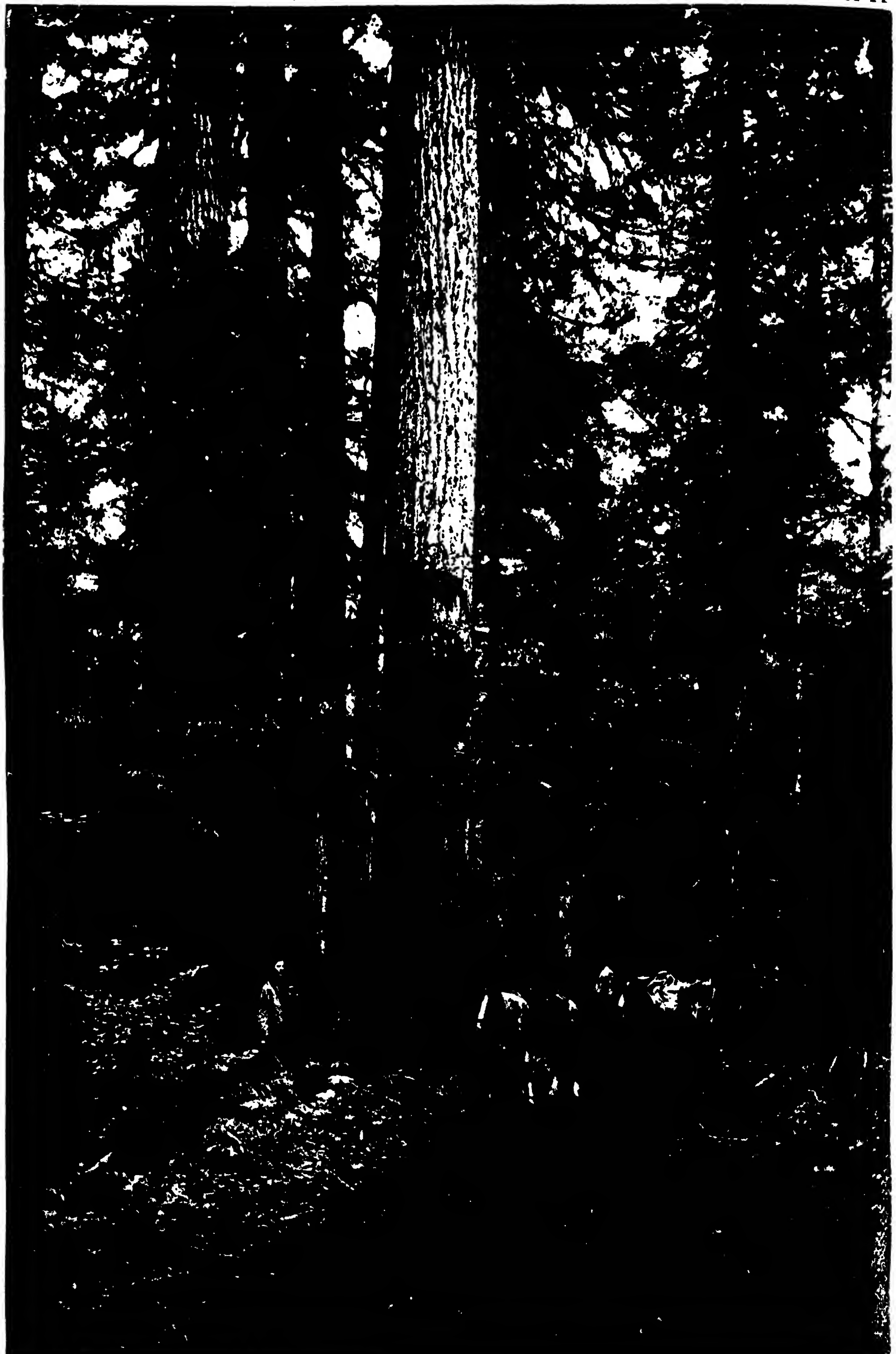
CLEANING BUILDINGS BY COMPRESSED AIR MIXED WITH SAND

On the same principle as the atomiser is the spraying-machine used in drenching fruit-trees with a poison that kills pests. It is by means of a blast of compressed air that hospitals and sick-rooms are disinfected. When such a blast is made more powerful, it can lift, dry, and aerate grain, or raise the culm from a coal heap to a furnace, and then discharge the ashes as they tumble from the grate. In sandy or muddy waters compressed air is employed to dredge a channel by stirring up the deposits at the bottom of the river or of the sea.

THE APPARATUS FOR SUPPLYING SAND AND COMPRESSED AIR FOR THE CLEANING OF BUILDINGS

When an air-compressor works in a reverse direction it becomes an air-exhauster, such as is used in large shops for sending a customer's money to and from the central office. The powerful in-draught of this apparatus often draws large pieces of paper or card into the pipes, and this peculiarity has led to the invention of an instrument for removing dust and dirt. The vacuum cleaner has now only to be cheapened to become a thing of high importance in modern civilisation. Dust is one of the chief carriers of disease; and the ordinary sweeping with a broom, the ordinary handling of a duster, do little more than stir up dirt for harmful redistribution. The vacuum cleaner, on the other hand, really cleans. It takes dust and dirt wholly away, and does its work with great rapidity. It is astonishing to see a pound of fine flour removed from a carpet in twelve seconds, leaving not a particle behind. When an instrument of this sort is used in the place of a broom in every cottage and mansion the general health of the nation will be much improved; the value of labour-saving machinery will literally, be "brought home" to every domesticated woman, and new ideas will be spread as to the mistake of concealing dirt, it being manifestly easier to remove it. Any change that brings mechanical power into woman's sphere is specially welcome, as hitherto inventions, being almost exclusively the work of men, have not been directed in anything like an adequate degree to lightening the labours that are regarded as distinctively in the province of women. The vacuum cleaner comes to take rank with the sewing-machine.

DOUGLAS PINES WAITING FOR THE AXE



A TYPICAL FOREST SCENE IN A WESTERN FOREST NEAR THE COAST

THE FOREST INDUSTRIES

Marvels that Science is Creating Out of Timber in the Race for Industrial Chemistry

THE ROMANCE OF THE LUMBERMAN'S LIFE

PROBABLY in no industry is the progress of applied science so evident as in the timber trade. Wood has been so largely displaced by steel and iron, brick and concrete, that it might seem at first glance as though the highly civilised races were becoming independent of the forests in which their ancestors lived. Coal and gas and oil have made logs a cumbersome and costly kind of fuel. The great trees once used in building have been ousted by metal girders and beams of armoured concrete. The large sailing-ships, for which mighty forests were once cut down, are now being built of steel and iron. Even their masts are made of metal. Wood is still generally used in making furniture, but we incline to think that less of it will soon be employed for this purpose. A modern house should not need in every bedroom heavy and clumsy wardrobes and other movable cupboards. A great deal of the furniture will soon be an actual part of the house, built into the walls, in some cases, and in others formed of recesses in the brick or concrete. Just recently Edison has succeeded in making furniture of a special kind of cement, smooth in texture and with a surface somewhat like wood. It is likely that in a few years this new furniture will be made and sold cheaply in large quantities. A considerable amount of it can be embodied in a house. The dwellings of the near future will not be mere empty boxes, but fairly well-equipped structures.

It is strange to think that only a few centuries ago iron was smelted in England by means of wood fires, and that wood was generally used for fuel and building purposes. One might fancy that timber was now becoming of little importance in modern civilisation. But in actual fact, in spite of all appearances, wood is growing more necessary and more valuable with every advance in industry and science. As fast as it is displaced in one trade, it becomes vitally useful in a new way.

For example, the ground that it has lost in ship-building and house-building has been more than made up by the timber required in making railway lines and wood pavements in cities. And it is not extravagant to say that the great coal and iron and steel industries are erected upon a wooden foundation. For every ton of coal taken out of a mine, a cubic foot of timber has to be put back. Wherever mining is carried on underground, it is necessary to shore up the walls and ceilings of the galleries with timber to keep them from caving in. This is one of the heaviest sources of expense in most mines, and a constant supply of cheap timber is indispensable to their running. It is not apparent what substitute will ever be employed for the purpose, so that a famine in timber would be an overwhelming disaster for mining interests.

Yet wood is becoming very costly. In our country, the consumption per head of the population has more than doubled during the last fifty years, and, of course, the price has gone up. This is not due to the fact that we have used up our forests, and rank next to Portugal as the most woodless of European States. For even in Germany, where a scientific system of afforestation has been followed for over a century, the price of wood has increased more than three times in the last fifty years. In all the large wood-exporting countries of Europe the price of timber has doubled and trebled, and, naturally, Canadian timbers have sold here at the high figures obtaining in Europe generally. All this goes to show that, in spite of various substitutes, the use of wood increases with advancing population and civilisation. And though an absolute

dearth of timber may be far distant, some valuable trees are in danger of extermination. We may expect a considerable enhancement of the price of the commoner kinds, as the supply has to be drawn from more and more remote sources. Already, real mahogany is uncommonly rare in the markets. The mahogany obtained from Central America is lighter and softer and different. That obtained from Africa is good, but distinct from the old-fashioned wood.

The Thoughtless Exhaustion of the Soft Woods of America

On the whole, however, the hard timber grown in tropical forests is less likely to become exhausted than the soft, resinous woods of the temperate regions of North America and Europe. Were it not for the extraordinary wealth of timber that Canada possesses, the outlook for many important industries throughout the whole civilised world would be very gloomy. The United States used to be regarded as an inexhaustible reservoir of timber. One forest stretched from the Atlantic shore to the Mississippi and beyond; another forest covered the Rocky Mountain regions; and a third great tract of woodland swept to the Pacific Coast. But the Americans were so wasteful and greedy with regard to their timber supplies that the Germans, twenty-seven years ago, foresaw what would happen—and began to take steps to profit by it. In 1885 a German forester was sent by his Government to study the timber trees of the United States. Very frankly he explained his mission to the Americans. "In fifty years," he said to them, "you will have to import your timber; and as you will probably have a preference for the American kinds, we shall begin to grow them now, so as to be ready to send them to you at the proper time."

The Predominance of Canada in the Forestry of the World

The United States have, as a matter of fact, begun to import wood, but instead of going to Germany the Americans of the North-Eastern States have turned to Canada. In many respects, the Canadians have been as wasteful of their forests as the American settlers. Destructive fires and wholesale clearing have greatly damaged the forests of eastern Canada that formerly stretched for over two thousand miles from the Atlantic to the head of the St. Lawrence basin. But, in addition to the southern forest belt, the eastern half of which is largely cleared, Canada has a great northern forest extending for 4000 miles to Alaska, with a breadth of some 700 miles. The Dominion is reckoned to possess a total forest area of 800 million acres.

It is difficult to realise what this means except by comparison. The two next most extensive timber-producing countries of which the details are approximately known are the United States and Russia. But the Canadian forests are about equal to those of the two other countries combined. Canada, in fact, has 43 per cent. of the chief timber resources of the world. And now that the Canadians are beginning to conserve their magnificent forests, cutting only the quantity of wood that is balanced by the annual growth, they are likely to govern the timber industry for many years to come. With a general scientific system of forestry they could command the wood trade for centuries.

Even the Canadians themselves are probably not aware of the consequences of the position that is within their reach. The lumber industry is capable of wonderful developments. Cutting up logs into planks and battens for export is really a fool's game.

The Extraordinary Determination of the Value of a Tree by Its Uses

A pine-tree is worth about £2 a ton. Cut and stripped, it fetches £3. Boiled into pulp for paper-making, it is worth about £8. When bleached, it sells for £11. But turned into viscose and spun into silk, it is worth £1100. At the present time five tons of artificial silk are manufactured in Europe every day. It is used for braids and trimmings, where it is much more brilliant than natural silk. It is employed to cover electric wires, and it is also mixed with other textiles, particularly silk.

It is also sold as a fabric alone and on its own merits. It does not appear in the shops as such. For while nearly every draper has a stock of artificial silk, he is often ignorant of the fact. But the truth is there is not enough natural silk manufactured in Europe to meet the demand. So it comes that a good many people now clothe themselves in garments made from wood. The wood pulp is treated with caustic soda and carbon disulphide. It can then be moulded into various kinds of useful articles, but it is more profitable to spin the viscose into long, silky threads which are decomposed into cellulose, and then made into fine, lustrous silk.

Besides helping to clothe us in this extraordinary way, the pine and spruce forests of Northern Europe and America look like becoming of great importance in

A LIFE OF CENTURIES COMING TO AN END


SAWING DOWN THE SPRUCE


FELLING THE KAURI TREE


CUTTING DOWN A GIANT SEQUOIA TREE


A GIANT OF THE FOREST FALLING

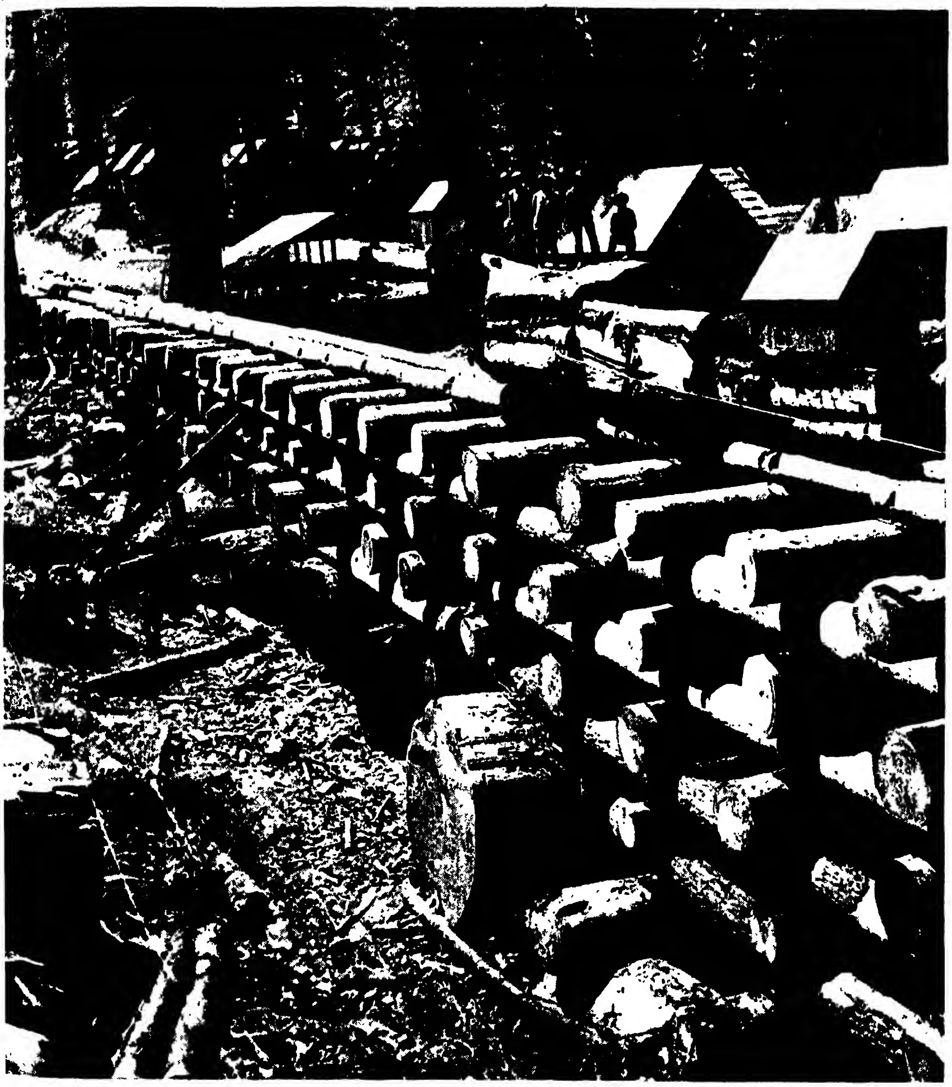
other ways. Already the wood pulp obtained from them forms the greater part of the paper used in modern books and newspapers and cardboard boxes. Every large daily paper in London or New York consumes each day fully ten acres of an average forest. A great deal of this wood-paper will not last, for the fibre out of which it is made is acted upon by light and air and water and the organisms of decay. Had Mr. Pepys written his famous diary on modern scribbling-paper, he would have remained an insignificant Admiralty official, for his work that keeps his name and character alive would now be but a heap of woody dust. Many of the books and journals in which are recorded in detail the events of the present age will not be of any use to the historians of the future. For they will not exist. We import every year more than 350,000 tons of the wood pulp that makes a very ephemeral paper.

Timber, however, can easily be converted into a paper with lasting qualities. The impurities are removed by chemical treatment, leaving a cellulose almost as pure as that obtained from rags. It is one of the great triumphs of the modern chemist that he has been able to take a deal board and pound and smash it up, and produce from the pulp a pure paper that will endure.

There are several methods of making the two hundred thousand tons of pure wood pulp which we import every year. In one method, a pine forest has to be near a deposit of iron pyrites. The pyrites are roasted and produce sulphur dioxide. This is passed up a high tower packed with limestone, down which a stream of water trickles. The burnt sulphur-gas enters into combination with the lime, and forms a liquid consisting partly of sulphurous acid and partly of bisulphite of lime. This strong fluid passes into a chamber filled with wooden chips and made very hot; it attacks the wood and eats up everything in it except the cellulose, which forms the walls of the cells of the living tree. The cellulose is then bleached by chloride of lime and sent to the paper factories, where it is made into paper that is so good that only an expert can tell the difference between it and rag paper. It

THE ENORMOUS GIRTH OF THE FOREST TREE—A RED WOOD TREE FORTY FEET WIDE

is doubtful if any chemical discovery of modern time has had a success so spontaneous and so immense in industrial value as this manufacture of excellent paper from timber. Even in pencil factories the waste wood is now a valuable by-product, which is made into a fragrant indiarubber from turpentine. Now, however, a group of British chemists, backed by several millionaires, have, at a cost of only £35,000, discovered a method of making excellent rubber from Indian corn and other cheap cereals. In a few years Great Britain will probably quite eclipse



HAULING LOGS ALONG A SPECIALLY CONSTRUCTED SKIDWAY

paper used for underlaying and preserving carpets with housewifely economy.

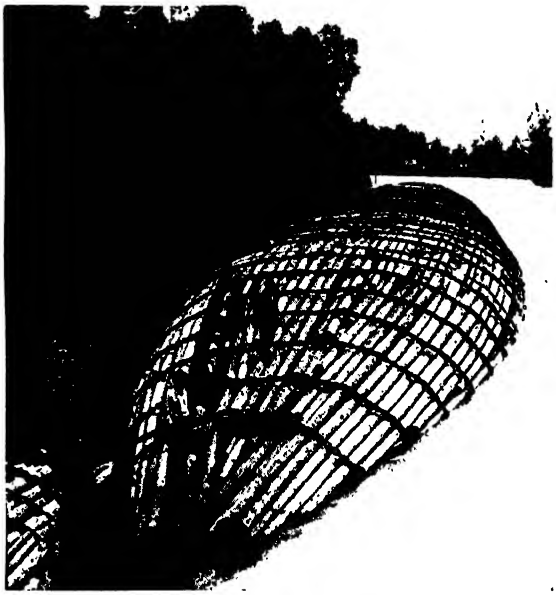
A month or two ago it seemed likely that the resinous woods of the Northern lands would be the foundation of an immense new rubber industry. For an English chemist, Sir William Tilden, succeeded in making a first-class synthetic Germany in industrial chemistry, and become the great world-centre of synthetic products of high and general importance. The timber industries of the Continent and of the United States will suffer to some extent from the extraordinary progress of British chemistry.

For at the present time the charcoal

trade is greatly benefited by the valuable by-product of acetone, which is essential in the manufacture of many modern explosives. Our country has been at a great disadvantage owing to its scanty stock of acetone, which is obtained by strongly heating wood in an iron vessel. If acetone were cheap, various industries would be able to expand, as chloroform and other useful solvents and drugs are obtained from it. Happily, acetone is one of the chief by-products in the manufacture of British synthetic rubber; and it is expected that our chemists will produce it so cheaply and largely that the process of distilling the wood will cease to pay. Instead of being at the mercy of Continental charcoal-makers, our nation will control both the rubber and the acetone industries.

But if pine timber is found to be too costly a source for the rubber on which all the world will soon move, it may yet provide one of the chief powers for driving motor-cars and machinery. For wood is easily convertible into alcohol; and a very cheap alcohol, produced in huge quantities, would entirely revolutionise motor traffic and the smaller forms of internal-combustion engines. The new wonder-worker the synthetic chemist who deals with maize and other starchy foods is engaged in a race against the chemist who is developing new industries out of timber. At the present time amyl alcohol, known in the trade as fusel oil, is being made very cheaply out of starchy substances by the same group of British chemists who have startled the world by the creation of inexpensive rubber and acetone. They look like defeating the foreign industrial chemists who use wood in the production of methyl alcohol, which is one of the elements of methylated spirits.

Methyl alcohol is obtained in the same process of wood-heating as ordinary acetone. When the wood is heated in an iron still a mixture of inflammable gases and vapours is evolved. These gases are condensed into a liquid, consisting of wood-tar and a dark, coloured, watery fluid that floats on the top. This fluid contains both methyl alcohol and acetone, and the two substances are easily re-distilled and separated. They then become important commercial products. Methyl alcohol is known in the trade as wood-spirit. It is used and misused for many purposes. In the United States it is drunk by the low negro population, who call it "White Horse" or "Old Mule." Much of it has appeared in witch-hazel, bay rum, eau-de-Cologne, Florida water, and red ink, and various essences and patent medicine nostrums. Poor, silly people sometimes drink wood-spirit, either as an alcoholic beverage or in some made-up form. In most cases there is a fairly uniform result. Out of ten men who each drink four ounces of methyl alcohol in any form whatever, four will probably die, two of them becoming blind before death. The remaining six may recover, but two of them will also become blind.



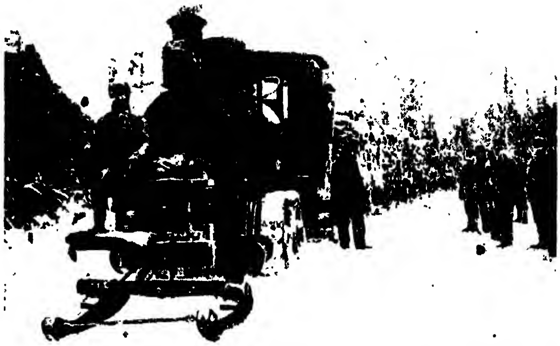
A LOG-RAFT ON THE COLUMBIA RIVER

This raft contained 65,000 logs, each 125 feet long. It was put together in a cradle up-stream, and towed down to the mills by steamer.

Even the absorption of the vapour through the lungs, or of the liquid through the skin, may produce permanent blindness. This is what makes the commercial use of wood-spirit, as a solvent for resins and shellac in the manufacture of varnishes, so dangerous. When an American Committee of Ways and Means went into the subject many of the witnesses that testified before it were blind wrecks that had once been hat-stiffeners, varnishers, or shellackers. They were men who had never drunk methyl alcohol, but merely handled it as a solvent in the course of their trade. Pure methyl alcohol seems to be dangerous

HARVESTING THE SPOILS OF THE FOREST

LOG-HAULING BY BULLOCK TEAM



A TRAINLOAD OF TIMBER ON SLEDGES

YELLOW PINE ON ITS WAY FROM AMERICAN FOREST TO MILL

DRAGGING TIMBER TO THE RIVERSIDE

TRAINLOAD AND TRAILER OF LOGS

even in an alcohol-lamp. So in methylated spirit only one part of it is mixed with nine parts of spirits of wine, in order to make it too nasty to drink and yet prevent it from being injurious to burn.

Apart from its poisonous qualities when drunk, pure alcohol is one of the most valuable liquids in modern civilisation. In useful properties it ranks next to water. Its solvent powers make it a magnificent industrial force. In an alcohol-lamp it is almost twice as efficient as kerosene. The alcohol-lamp furnishes 30·35 candle-power for fifty-seven hours five minutes for one gallon of alcohol. A kerosene-lamp, on the other hand, furnishes 30·8 candle-power for only twenty-eight hours forty minutes with one gallon of oil. The alcohol-lamp is, moreover, very pleasant and safe. It cannot smoke; it gives off no offensive odour and little heat; it is not affected by draughts; its wick does not burn; and if the alcohol is spilled it evaporates, leaving no stain on the carpet and no smell on the hands. It is so safe that even the most particular insurance companies make no objection to its storage.

The heating power of alcohol is also very good. In internal-combustion engines it is certain sooner or later to displace petrol. It does not plug the cylinders and valves with waste products, as petrol does. Again, petrol cannot be compressed more than eighty pounds to the square inch without a danger of premature explosion, while the compression of alcohol vapour may safely be carried to two hundred pounds. The only real disadvantage of alcohol is that it possesses only six-tenths of the heating value of petrol, but this will not matter when alcohol can be sold at a cheap rate. For by compression alcohol vapour can be made more powerful and more portable than petrol.

LOGS FLOATING DOWN THE ST. MARIE'S RIVER, IDAHO, BOUND FOR THE SPOKANE MILLS

The bearing of all this on the timber industry lies in the fact that alcohol can be manufactured from cellulose. We have already seen that a wonderfully cheap and almost pure cellulose can be obtained from deal by pounding it into a pulp and treating it with chemicals. From this wood cellulose there is now being produced a cellulose alcohol—a quite different thing from wood-spirit—which is practically certain to be very much cheaper than the alcohol obtained from maize and potatoes

THE LAST STAGE BEFORE USEFULNESS

LOGS AT A SAWMILL AT THE END OF THEIR JOURNEY DOWN STREAM

HOISTING LOGS ON AN ENDLESS CHAIN FROM RIVER TO SAWMILL
The upper photograph is by courtesy of the Canadian Government

and other starchy substances. One chemist claims that he has extracted twelve gallons of alcohol from one hundred and ten pounds of wood shavings. So that sawdust and other waste products of sawmills, carpenters' shops, and other industries relating to wood may soon become of great value.

There already exist many patented processes for the transformation of cellulose into alcohol. Most of them that promise very high yields of spirit may not yet be of general industrial practicability, but there can be little doubt that one or more of these processes will, in the immediate future, bring about an extraordinary change in the timber industry, more far-reaching and beneficial even than the wood-pulp discoveries.


A LUMBER FLUME, ON WHICH BEAMS ARE FLOATED FROM FOREST MILL TO RAIL ROAD

When a clean, safe, and sound alcohol can be made from wood pulp and sold in vast quantities at threepence a gallon, the internal-combustion engine will drive most of our machinery and most of our vehicles. A great many articles of common use that are manufactured by means of a solvent will also be cheapened. The event may happen any day. Certainly it will occur in a year or two. Besides timber, stubble, straw, chaff, and rags will all be mines of industrial alcohol. But naturally the great forests will be by far the most important source of the new and mighty power of the twentieth century. If only the Canadians cut their immense forests in a scientific way they will be able to control some of the greatest industries in the world.

The people of the United States once had an excellent chance of rivalling the Canadians. Through thoughtlessness, wastefulfulness, hurry, and greed, they lost their opportunity; and even if they were now generally alive to their loss it would take them a hundred years and a considerable amount of money and science and care to recover the position they have forfeited. The people of Great Britain, however, cannot attack their American kinsmen for missing the wealth of the woodlands. Only four out of every hundred acres in the British Isles are now covered with forest trees. Yet it is scarcely a hundred years ago since we grew the best timber in Europe, and had little or no need to import any woods except fine tropical trees used in the best kind of furniture. Now we spend more than thirty-five millions sterling every year in importing timber, wood pulp, and other forest produce. With the exception of Portugal, that has only three wooded acres to every hundred acres of land, we are more beggared of timber than any race in the world.

In Europe generally 30 per cent. of the total area is forested, and, in spite of the enormous growth of the population, there are two acres of woodland to every living person. In Russia, 40 per cent. of the land is forested, and so it is in Sweden. In Bosnia, more than half the country is covered with trees; in Bulgaria, forty-five out of every hundred acres are wooded. Germany has 26 per cent. of its area under a scientific system of afforestation. Austria-Hungary has 30 per cent., but it is not so well husbanded. Norway has 21 per cent., and France has 18 per cent., which is excellently managed. Even Spain, that is sometimes thought to have become dry through the felling of the forests, has seventeen out of every hundred acres covered with trees.

In many of these countries wood is largely used as fuel. Even in Germany there are heavy local demands for fire-logs. Yet not only is this met, but timber is exported in considerable quantities to our country and to other lands, without diminishing the forests. The annual growth per acre is fifty cubic feet of wood. Only forty-seven cubic feet of this is cut down every year, bringing in a net profit of about 3s. 6d. an acre. The Prussian Government owns six million acres of forest, from which it derives yearly

THE HAZARDOUS SEASONING OF TIMBER

A LARGE LUMBER-MILL ON THE OTTAWA RIVER

A BIG LUMBER-YARD AT SHANGHAI, CHINA

A FIRE AT A LUMBER-MILL, IN WHICH FORTY MILLION FEET OF WOOD WERE BURNT

AN OUTPOST ON ONE OF THE GREATEST OF THE WORLD'S FEW REMAINING TIMBER RESERVES

A TYPICAL SCENE AT A LUMBER MILL IN THE FOREST REGION OF THE PACIFIC SLOPE

over a million pounds sterling, after paying all expenses. Russia possesses 516 million acres of forest land. But, though she exports about £6,000,000 of timber to our country alone, she cannot be regarded as a permanent source of timber supply to Europe in the coming years of demand.

The Russian is almost as wasteful of wood as the American was. Nearly half of the annual cut of his forest is burnt by him for fuel, and a large amount of wood is used for house-building. There is a saying that Russia is burnt down every seven years; and this constant destruction of the timber houses by fire, and the steady and large increase of the Russian population, are bringing about a disastrous restriction of the forest area. Every year the growing export of timber at Archangel and other White Sea ports is drawn from a greater distance inland. In short, the mighty forests of Russia are going the way of the vast forests of the United States. In probably a generation or less, Russia may be buying timber from Sweden and Germany. Only brick houses and coal fires, and a rigid system of forest conservation, will save the Russians from bankruptcy. For when all the cheap timber is gone, there will be a serious rise in the cost of living. This has happened in the United States, partly owing to higher rents and the gradual disappearance of the cheap log-house and shingle cottage.

PROTECTING THE ENDS OF STACKED TIMBER TO PREVENT SPLITTING WHILE SEASONING

In the United States the great forests were an important factor in the peopling of the country. It was mainly cheap timber that enabled the settler to build a dwelling-place quickly and at little cost. It is not extravagant to say that the rough but sound log-house was one of the principal foundations of the prosperity of the American nation. The forest enabled the migrating farmer to win his way with small capital and hard work · and the great amount of wood that he used for fuel helped to clear the ground for tillage. As a matter of fact, the backwoodsman hated the great trees that surrounded him. He derived his sustenance from the woods, but he did so by destroying them. In his view, the fall of a tree was an advance of civilisation. The ugly, cheerless look of his clearing, with fire-blackened stumps, or, worse, with the trunks still standing upright but killed by girdling, and the rude, savage aspect of his wood cabin, were for him the hopeful signs of victory over hostile Nature.

To him the woods were something to be got rid of. He had travelled through them, slowly toiling along the trail, carrying his pack of provisions to maintain life, or gliding down the interminable windings of the river. The forest was his enemy, and one that he never hoped really to conquer. East and west, north and south, he knew that the great trees extended for hundreds and hundreds of miles. After slow, hard, and painful work he made a clearing just a few acres in extent, that was scarcely noticed in the vast expanse of woodland. The idea that the area of the forest could ever be diminished to any appreciable extent by human hands, so that people would become afraid of not having woodland enough to supply them with necessary timber, would have seemed to him an utter absurdity. Of course, where settlers came in thick and fast, the forest might disappear and farms take its place. But there was always plenty of timber a few miles further on. Thus arose the legend of the inexhaustible supply of lumber in American forests, which has only been exploded in the present generation pledged to scientific industry.

After the backwoodsmen came the lumber kings, who saw that the export of timber was a double source of riches. On the one hand, they made fortunes by cutting

down trees and sawing them up for sale at home and abroad. And, on the other hand, they were able to dispose of the cleared land at a good price to farmers. Then they went on to the next tract of woodland ahead of them, and continued what they often sincerely thought was a profitable and necessary work of civilisation. It was these shrewd and fairly well-meaning men, armed with rough but powerful machinery, who ate up the forests of the United States with as fierce a destructiveness as a cloud of locusts devours the green wealth of a sown field. Never were the primeval forests of an immense country so swiftly, wastefully, and greedily destroyed as they were by the American lumbermen.

A similar work of thoughtless destruction is still being carried on in some parts of Canada. No one can travel through the Dominion without being struck by the waste of timber that has been permitted in the past, and still goes on in many places at the present time. The waste is most apparent in the ravages of forest fires, the effects of which, especially in British Columbia, are the distinguishing features of the landscape for hundreds of square miles. But wood is apparently held very cheap, apart from this devastating influence. For huge quantities of it are to be seen scattered up and down the rivers, lakes, and elsewhere, as if it were derelict and of no practical utility. As in the United States some years ago, the area of forest lands is so vast that many men appear to think that it is impossible ever to overtake the supply.

And to the settler the thick growth of trees that has to be cleared seems an individual curse instead of a national blessing. Yet only a few years ago, when the maritime provinces of the Dominion appeared to possess as inexhaustible timber resources as the western provinces seem to have to-day, timber lands could be purchased for about a fifth part of their cost at the present time. Thus, even in Canada, with its thousands of miles of wooded country, there has recently been a very great rise in the value of forest land. The high importance of this fact in the timber industry generally is clearly brought out when we remember that Canada will soon control the wood trade of the whole world. The prices fixed by the Canadians will govern those of all other countries.

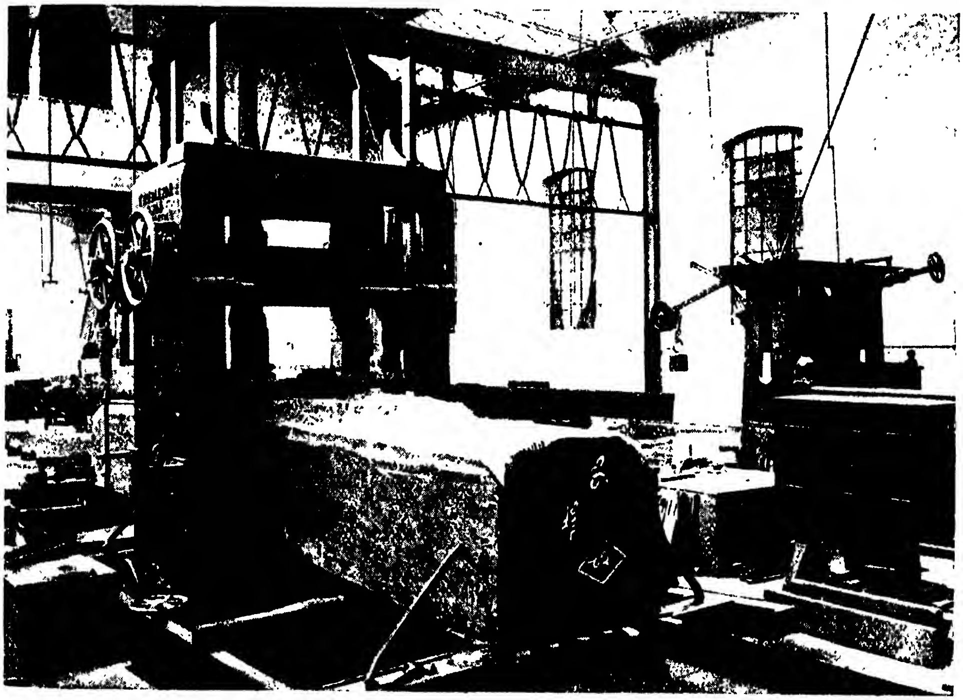
MACHINES IN A PAPER-FACTORY REMOVING THE BARK FROM LOGS

As the great railways of the Dominion extend and ramify, the lumber industry will become a routine and scientific business. But in many places in Canada it is still one of the most picturesque and exciting of large employments. An interesting class of men, known as woodsmen or cruisers, explore the country in search of good tracts of pine timber. They sell their information to a lumberman; and when the lumberman has acquired a body of merchantable pine, he sends a small crew into the woods to make preparation for the winter's cutting. A camp is built of logs; rough roads are made, along which supplies for

crew and cattle can be hauled into the forest, and with the first cold weather work begins. Most of the felling for lumber is done in the winter in the pineries of North America. Hemlock is cut in summer, because the bark of this tree, which is of more importance than the wood, must be handled in warm weather.

Work in a lumber camp is not an easy affair. It takes skill as well as strength and endurance. When a tree has come to the ground, it is at once cut into logs, leaving as waste the branches and the upper part of the main trunk that is below log size in diameter. The logs are rolled on skids, and hauled to the river bank by horses. Very deep snow is troublesome to the lumbermen, yet the absence of snow is a calamity. For only snow or ice, produced by flooding the road in cold weather, can make the rough logging-tracks passable for the heavy loads. In a well-managed camp no beer or spirits is allowed. The use of alcoholic liquors might mean death to a man working in the open air with the thermometer far below zero. But the crew is given as much hot tea or coffee as anybody wants to drink. They are also fed on good and abundant food, for their work can only be done with excellent and large meals. A niggardly logger would be quickly deserted by all his crew. Wages are paid at the end of the season, when the camp breaks up; and a man who has worked steadily all the winter draws a considerable sum of money in the spring.

After a few days' interval between breaking camp, the "drive" begins, which is the floating of the logs down the river. The logs are sent on their voyage as soon as the ice in the river breaks up. Of all the operations required in the progress of the pine-tree into paper or deal boards, this is the one requiring the greatest hardiness in the workman. As the logs travel down the waterways, they have a distressing habit of floating to the wrong places, getting stranded on sandbars or snags, running into sloughs, and trying to escape from human control in other ways. So a crew has to follow the long procession of logs, and keep the wandering wood in the main channel by means of long-handled hooks. In this task, it is often necessary for the men to jump from one floating log to another; and in spite of the sharp, stout spikes with which their boots are furnished, they find that taking an involuntary bath in the icy water is just as easy as rolling off a log.

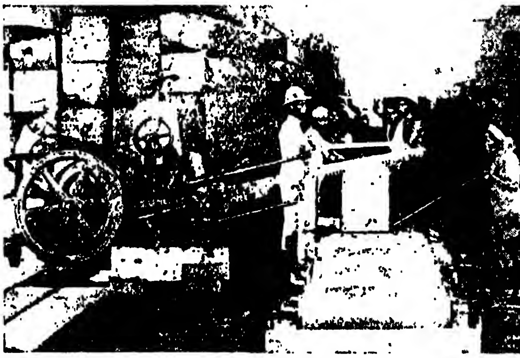


POWERFUL MACHINERY SAWING A LOG INTO A SCORE OF PLANKS AT ONE OPERATION

The hardships and hazards of the crew culminate when a log-jam is formed, which usually occurs in one of the rapids that abound in many logging rivers. For then the men are compelled, often at the immediate risk of life, to break the jam by removing some of the logs that have struck against the rocks, and that hold the timber above them tight on the river. Many lives have been lost by the impetuous rush of the logs when these key-logs began to move.

In mountainous regions lumbering is more difficult than by rivers. For a great timber-slide has to be built down the height; and from the top of the drive a logging railway often has to be laid into the forest region. When a slide has to be built down a mountain slope, a novice would suppose that a straight inclined plain would afford the speediest path for the descending wood. But it is not so. The best and fastest slide is that made on the peculiar curve known as a cycloid. An easy way of tracing a cycloid is to place a wheel close to a wall and fit into the rim of the wheel a pencil of which the point presses against the wall. As the wheel rolls along the floor, the pencil will draw on the wall the kind of cycloid that makes the quickest slide for logs down a mountain. On some of the great lakes the logs are still at times built into immense rafts, that are towed by two steamers, one forward and one behind, to keep the huge floating structure straight in the channel. But even then there is great risk of the rafts breaking up in a high sea and scattering the logs; so this method is now seldom used.

Another great change is taking place in the lumber industry, with the extension of railways. Instead of floating the logs down the stream, when the snow melts and the water rises, and taking them by this means to some central sawmill in or near a large town, most of the work of converting timber is done in the forest. The sawmill is erected in the very heart of the woodland, and often run night and day during the season by means of an electric arc light. In many cases a planing-mill stands beside the sawmill, and the raw lumber is worked into finished carpenter-work before it is sent from the forest.



CUTTING TIMBER IN A SAWMILL AT SHANGHAI

A great modern sawmill is a very ingenious piece of mechanism. One of the most remarkable things about it is the manner in which the expensive handling of the material by human labour is avoided through the use of endless chains, inclined planes, and other appliances of automatic machinery. It is really a wonderful spectacle to see a log drawn from a mill-dam to the saws by an endless chain, and sawn up, and then shaped into some finished article by practically automatic planes and lathes.

When all the wood used in these marvellous forest industries is properly seasoned before it is converted into doors and window-frames and various other forms of carpentry, the present work of many carpenters in cities and towns will be taken away from them. The carpenter, however, will probably find a new opening for his skill in fashioning the immense number of wooden moulds that will soon be required in erecting houses and buildings of cheap but imperishable reinforced concrete. He will recover his old position at the expense of the bricklayer and stonemason; and these men, if they are wise, will become concrete-handlers.

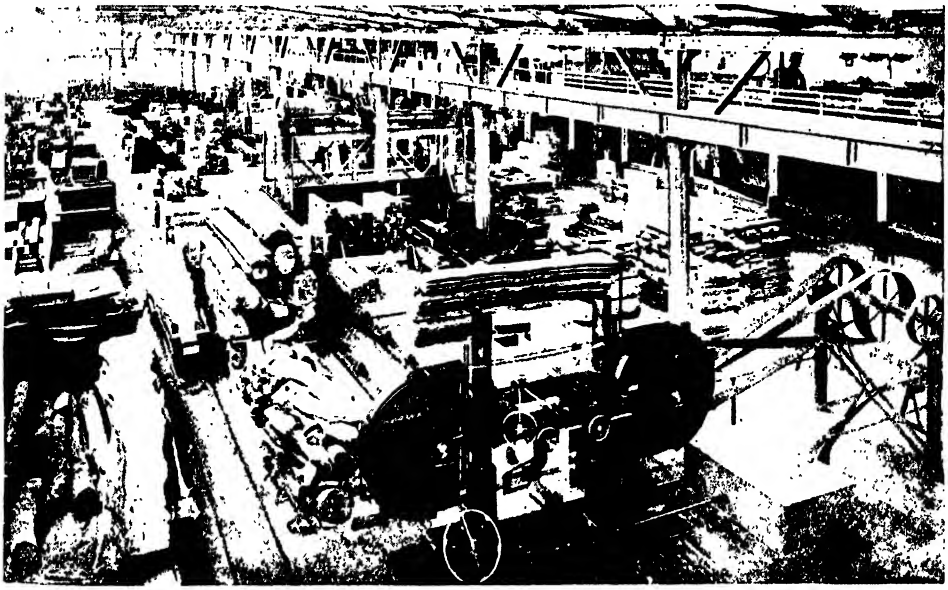
At the present time, the new forest industries suffer from disregard of the problem of seasoning. A few weeks ago we saw, in one of the picturesque red-tiled houses in the new London suburb of Golder's Green, a machine-made door from a Northern American forest, which had so shrunk in about a year that chinks were formed in it in several places. Anybody in the hall could see into the room without opening the door. The valuable Australian timber industries have been seriously injured owing to the wood being exported in an unseasoned condition.

By stacking timber well above the ground, so that the damp cannot reach it, while the air freely circulates between and around all the wood, the strength of the pieces is nearly doubled. Not only is the water evaporated, but certain substances in the wood are dried

out or decomposed, rendering the timber much less liable to decay by fermentation. Natural seasoning is the best, but it takes a long time. A thick piece of oak, for instance, requires twenty-six months to season; even soft fir takes more than a year to get in good condition when it is very large. So several methods of artificial seasoning are now largely employed.

Kiln-drying is a rapid but expensive process, and it is liable to harden the outside of heavy woods and honeycomb the interior with holes. It is said that steam-drying reduces the strength of wood, and that boiling timber in water has the same effect. Charring the outside of the wood seems to be a good method. For charred stakes found in the bed of the Thames, near Weybridge, and there used by the ancient Britons as a defence against the invading Romans, have lasted well. So have the charred piles upon which the Venetians built their city of the sea. The Burmese have an excellent method of seasoning the teak-trees which have now largely displaced English oak. They cut a complete ring through the bark and sapwood of the standing tree three years before it is felled. This stoppage of all the ascending sap kills the tree in a few weeks. The heat of the climate helps the seasoning process; and, as about a year elapses between felling the timber and its delivery in England, it is then fit for immediate use. This process is called girdling; and it is reckoned that the fine, useful, heavy wood of the Australian forests could also be seasoned by girdling. It would then command a large sale.

At the present time the teak-tree, that grows in India and the Burma States, is the most useful of heavy woods. It is the most durable of known timbers, and it contains a resin that prevents nails and screws used in it from rusting, and that keeps injurious insects and sea-worms from attacking it. It is easily worked, and it is superior to pine and oak in its freedom, when seasoned, from any change of form or warping, even under the extreme climatic variations of the monsoons. The Indian Forest Department plant thousands of acres of teak every year, so there is little fear of the exhaustion of the supply. Happily, Great Britain at present has a practical monopoly of teak. It is used in our battleships for backing armour-plate and making deck-planks. Some of our railway waggons are also made from it, and it is coming into use for railway sleepers, bridges, and furniture.

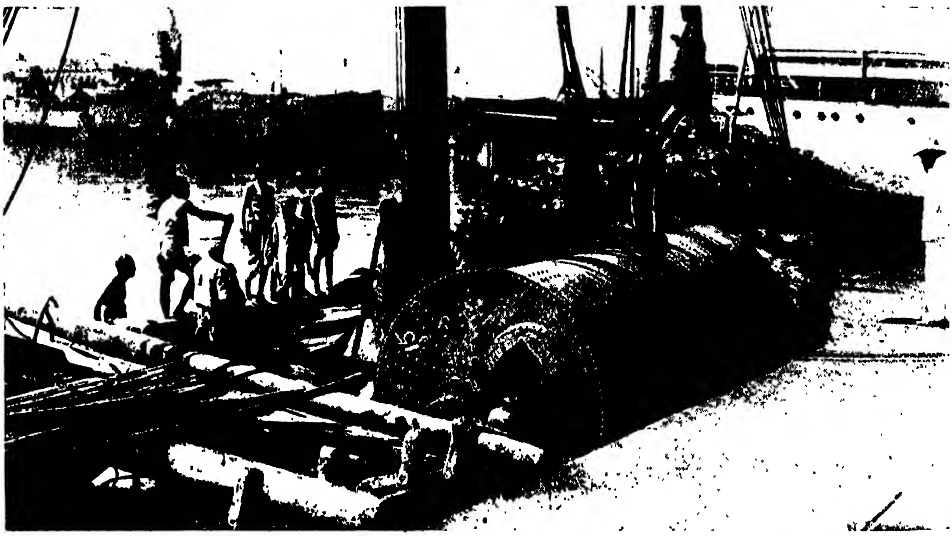


AN UP-TO-DATE SAWMILL AT ENGINEERING WORKS ON THE TRENT

Taking the British Empire as a whole, its timber resources are incomparable. When the Canadians and Australians manage their forests with the care exercised by our Indian Forest Department, the sons of the woodless British Isles will control through the ages the manifold and immense forest industries on which the future of the civilisation of the world now largely depends.

BRITISH WORK ON THE WAY TO ALL LANDS

A TRAINLOAD OF BRITISH-MADE BOILERS EN ROUTE FOR A SHIPPING PORT



A BOILER EXPORTED FROM ENGLAND ARRIVING AT A CHINESE PORT

ELEPHANTS TRANSPORTING AN ENGLISH-MADE BOILER UP-COUNTRY IN INDIA

These photographs and that on page 2671 are by courtesy of Messrs. Marshall & Co., Gainsborough

OUR TRADE IN MADE GOODS

Proofs from Our Oversea Traffic that We Earn Our Essential Supplies Mainly by Metals and Textiles

WHERE WE SUCCEED AND WHERE WE FAIL

Having considered our commerce in food and in raw materials, we come to the consideration of the chief means by which we earn our imported supplies—viz., our commerce in manufactured articles. Writing in 1847, Porter, in his well-known "Progress of the Nation," said: "England has long stood pre-eminent for the skill of its inhabitants in manufactures of various kinds. But for that skill, and the extraordinary degree of development which it has experienced during the past half-century, it is not possible to conceive that this country could have made the financial efforts which enabled us to carry on the long and, beyond all precedent, the expensive war of the French Revolution . . . It is to the spinning-jenny and the steam-engine that we must look as having been the true moving powers of our fleets and armies, and the chief support also of a long-continued agricultural prosperity."

If the last words hardly hold good some seventy years after, it is undoubtedly still true that British manufacturing skill is our mainstay, and a thing to be cherished as fundamentally necessary to the continuance of British power and prestige. In Chapter 8 (page 997) we gave the broad details of the oversea trade of the United Kingdom in 1910.

We saw how striking was the difference between our inward and outward shipments—the inward consisting chiefly of food for men and food for factories, while the outward consists, for by far the greater part, of coal and manufactured articles—mainly as to bulk the former, and mainly as to value the latter. We give below a summary of the facts adduced, and the diagram on the following page will help to impress the facts of the case upon the reader's mind.

IMPORTS OF UNITED KINGDOM IN 1910

Class of Goods	A Total Imports	B Re-Exported	C For Home Use	D Exports
	£ 000's omitted	£ 000's omitted	£ 000's omitted	£ 000's omitted
Food, drink, tobacco	257,800	12,900	244,900	26,100
Raw materials	261,200	63,300	197,900	53,400
Manufactures	156,900	27,400	129,500	343,000
Miscellaneous	2,500	200	2,300	8,100
Totals	678,400	103,800	574,600	430,600

Passing to the consideration of that part of our trade which is concerned with manufacured goods, we see that in 1910 our imports of foreign and Colonial manufactured goods for home consumption were valued at £129,500,000, and that our exports of British manufactures to foreign countries and British possessions were valued at £343,000,000. In further analysis these figures yield remarkable results. They greater part of our imports of manufactures are under the two great heads Metals and Textiles. This will be clear from the following statement, showing that metals, metal goods, and textiles account for the greater part of both our imports and exports of manufactures.

METALS, METAL GOODS, AND TEXTILES

—	Net Imports of Manufactures for Home Use	Exports of British Manufactures
	£	£
Metals	40,100,000	109,400,000
Textiles	37,100,000	166,900,000
All the rest ..	52,300,000	66,600,000
Total ..	£129,500,000	£342,900,000

Here we see that the £129,500,000 of imports consisted as to £77,200,000 of metals and textiles, while the £342,900,000 of exports consisted as to nearly £276,300,000 of metals and textiles. A vast number of miscellaneous manufactures are included under "All the rest"—furniture and other manufactures of wood, chemicals, drugs, paints, colours, leather goods, glass, china, earthenware, paper, stationery, indiarubber goods, and many other things. Important as many of these productions are, our export of them is very small as compared with our main staple exports of metals and textiles.

Details of our commerce in metal manufactures, in which our exports of British make are well over one hundred millions a year, are for 1910 as follow.

COMMERCE IN METAL MANUFACTURES

Manufacture	Imports: Gross	Imports: Net, after Deducting Imports Re-exported	Exports, British Make
	£ 000's omitted	£ 000's omitted	£ 000's omitted
Iron and steel	9,094	8,769	43,003
Other metals..	24,099	17,354	10,360
Cutlery, hardware, etc.	4,674	3,927	6,424
Electrical goods	1,686	1,481	4,118
Machinery ..	4,471	3,528	29,297
New ships ..	27	25	8,769
Railway carriages, cycles, motors	5,607	5,033	7,453
Total Metals	£50,258	£40,117	£109,424

The most important of these items, and that which demands our first attention, is the general heading "Iron and Steel Manufactures," which stands for all forms of iron and steel, from pig-iron and crude steel to hoops, tubes, pipes, plates, sheets, wire, nails, screws, and rivets, bolts and nuts, railway and tramway rails, wheels, tyres, and axles, girders, beams, joists, etc. It will be perceived that our exports of iron and steel are enormously greater than our imports. It does not appear, however, that our exports in recent years have been progressing in proportion to the very greatly increased demand of the world at large.

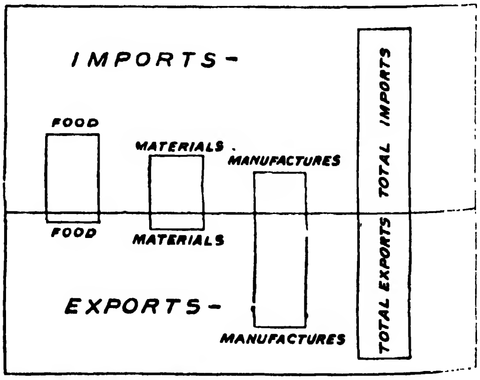
The position in the iron trade is, broadly, as follows: the world as a whole is hungry for iron; the rapid growth of the world's railways, which were illustrated in Chapter 13, alone sets up a demand of very great dimensions, and of very rapid growth. In addition, iron is being increasingly used in building and engineering, and its miscellaneous uses are, of course, very numerous. Only three countries are in a position to meet this demand on a large scale, and those three countries are the United States of America, the German Empire, and the United Kingdom. The United Kingdom is therefore in the fortunate position of being one of the few favoured suppliers to a market of huge and rapidly swelling dimensions. Under these circumstances, our exports have not been growing so rapidly as might have been expected. If we look at the long record of our exports of this kind since 1850, we get the very interesting table given below.

BRITISH EXPORTS OF IRON AND STEEL

Year	£	Year	£
1850 ..	5,350,000	1895 ..	19,428,000
1855 ..	9,369,000	1900 ..	31,623,000
1860 ..	13,673,000	1905 ..	31,826,000
1865 ..	15,427,000	1907 ..	46,662,000
1870 ..	25,537,000	1908 ..	37,406,000
1875 ..	25,644,000	1909 ..	38,192,000
1880 ..	27,225,000	1910 ..	42,977,000
1885 ..	21,449,000	1911 ..	43,752,000
1890 ..	31,063,000		

It will be seen that as long ago as 1890 British exports of iron and steel reached £31,000,000. Ten years later, after an intermediate period of bad trade, they slightly exceeded this figure. In 1905 they were the same as in 1900 and 1890. In 1907 they touched a record figure of £46,662,000. Since then they have remained below this figure, and last year they were just under £44,000,000. There has thus been an increase since 1890 of about £13,000,000.

THE STRIKING CONTRAST BETWEEN BRITISH IMPORTS AND BRITISH EXPORTS



The columns above the line represent imports into the United Kingdom for home use. The columns below the line represent our exports of British goods only.

The explanation is to be found in the enormous progress made in foreign iron and steel industry in recent years. Germany and America have robbed us of the premier position in production, and are now not only meeting their home demand but playing their part in satisfying that world hunger of which we have spoken. This is particularly true of the case of Germany. The rise of German iron and steel exportation has been phenomenal; it has doubled in the ten years 1900–1910. The following statement shows the progress of the three chief iron and steel nations in exportation in the last twenty years.

BRITISH, AMERICAN, AND GERMAN EXPORTS OF IRON AND STEEL

—	Britain	United States	Germany
	£	£	£
1890	31,100,000	1,800,000	11,300,000
1900	31 600,000	12,700,000	19,900,000
1905	32,500,000	13,300,000	25,500,000
1910	44,000,000	18,400,000	34,400,000
1911	44,800,000	23,500,000	41,300,000
Increase ..	13,700,000	21,700,000	30,000,000

In 1911 Germany advanced to a point nearly on a level with the United Kingdom. At this rate, Germany will soon be the chief iron and steel exporting country. The United States is not yet playing as great a part in the iron and steel export market as either Britain or Germany, and this in spite of the fact that her production of crude metal is as great as that of the other two countries put together. The explanation is that the United States has been meeting the enormous demand of her own vast territory. Of railway metal alone, the United States consumes very large quantities within her own borders. It is probable, however, that America will take a greater share of the iron and steel export market in the future. Between German and American competition, it is obvious that British iron and steel exporters have much to do to increase, or even to maintain, their oversea trade. Nevertheless, the peculiar advantages which Britain possesses in this manufacture should enable her to play a great and increasing part in this particular branch of commerce.

Here is a statement which will show how keen is the competition between Britain and Germany in some branches of the trade.

BRITISH AND GERMAN COMPETITION IN THE IRON AND STEEL TRADE—1911

—	German Exports	British Exports
	£	£
Pig-iron	2,500,000	3,900,000
Steel ingots, blooms, and billets	2,700,000	40,000
Wrought-iron bars, etc. ..	6,600,000	1,100,000
Plates and sheets (not galvanised)..	2,800,000	2,600,000
Galvanised sheets ..	(?)	7,600,000
Tinplates	(?)	6,800,000
Wire	2,900,000	2,400,000
Rails	2,800,000	2,300,000
Railway wheels and axles.	1,000,000	1,000,000

It will be seen that in the exportation of crude steel we hardly play any part at all, while Germany has a great exportation. On the other hand, our exportation of galvanised sheets and tinplates is very great, while that of Germany is very small. In wire and in railway metal the two nations are running neck and neck.

We have already discussed (Chapter 16) the comparative iron and steel productions of the leading countries in the iron trade, and their comparative advantages. The facts we have here adduced should impress us with the essential character of the industry in its relation to our general commercial position, and urge us to leave nothing undone to secure the efficiency and progress of a trade so intimately bound up with the national welfare.

We may here add to the exceedingly important information given on page 1953 (Chapter 16) by recording the pig-iron and steel production of the four leading nations for the year 1911.

PRODUCTION OF IRON AND STEEL BY THE FOUR LEADING NATIONS IN 1911

—	Pig Iron	Steel
	Tons	Tons
United States ..	23,600,000	23,500,000
Germany	15,300,000	14,600,000
United Kingdom ..	9,700,000	6,500,000
France	4,400,000	3,600,000

If these figures are compared with those on page 1953, it will be seen that the United Kingdom output of pig-iron again dropped back, while that of Germany increased considerably. With regard to steel, the British figures rose again slightly, but only to the level of 1906, whereas the German figure showed an increase in 1911 over the previous year of 1,100,000 tons. Thus the figures of another year rather worsen the comparative position shown in the striking tables on pages 1953 and 1954.

Almost every country in the world is a customer in some sort for one or other branches of our iron and steel trade. Our railway metal, wire, plates, galvanised sheets, tinplates, tubes, nails, screws, bolts, etc., find their way to the Near and Far East, to South America, to every British colony, to European nations, even to Germany and the United States. On the other hand, our imports of iron and steel are drawn from few countries, for, of course, few countries, as we have seen, are able to export iron and steel.

If we use the term "iron and steel trade" to cover every sort and kind of article produced from these metals, we get the enormous export figure of about one hundred millions sterling. As will be gathered from the last column of the table on page 2674, with the exception of the second line in that table, "Other metals," the aggregate export of metals in 1910, valued at £109,400,000, consisted almost in its entirety of iron and steel or things made from iron and steel.

The chief item is machinery, which reached £29,297,000 in 1900, while the imports of the same kind were worth only £3,528,000.

This branch of our commerce also calls for special consideration, and it will be well to show how and what the machinery we exported in 1910 consisted of, and to what countries it was sent. The following statement gives this information

BRITISH EXPORTS OF MACHINERY IN 1910

1. MACHINERY (OTHER THAN ELECTRICAL), PRIME-MOVERS :

	£
a Locomotives for rails : Argentina, £505,000 ; other South American countries, £212,000 ; India, £331,000 ; S. Africa, £287,000	1,707,747
b Road locomotives	460,040
c Agricultural motors, including South America, £325,000 ; and Europe, £638,000	1,243,991
d Pumping engines	528,609
e Winding engines	78,070
f Miscellaneous prime-movers : Europe, £1,007,000 ; South America, £302,000 ; S. Africa, £144,000 ; India, £313,000 ; Australia, £372,000	2,938,738
Total prime-movers ..	£6,957,795

2. MACHINERY (OTHER THAN ELECTRICAL), NOT PRIME-MOVERS :

g Agricultural machinery : Europe, £942,000 ; South America, £248,000	1,443,302
h Boilers..	£1,477,31[illegible]
i Machine tools	714,0[illegible]
j Mining : S. Africa, £618,000 ; India, £80,000 ; Australia, £69,000	1,280,0[illegible]
k Sewing-machines and parts ..	1,730,5[illegible]
l Textile machinery : Russia, £876,000 ; Germany, £869,000 ; France, £825,000 ; Japan, £362,000 ; U.S.A., £1,142,000 ; India, £1,230,000 ; South America, £404,000	7,614,20[illegible]
m Typewriters	19,4[illegible]
n Miscellaneous	6,430,82[illegible]
Total of (2)	£20,710,9[illegible]

3. ELECTRICAL MACHINERY ..	1,602,67[illegible]
Total of (1), (2), and (3)	29,271,38[illegible]
Add cycles	1,957,287
,, Motor-cars..	2,005,527
,, Motor-cycles	160,47[illegible]
Grand Total	£33,994,67[illegible]

This statement reveals at once the strength and the weakness of our commerce in the products of the engineer's workshop. It should be noticed that almost the entire exportation is confined to engines and machinery "other than electrical." Out of a total exportation worth nearly £34,000,000 in 1910, electrical machinery accounted for only £1,600,000. Indeed, so little impression did electrical machinery exports make upon the trade returns that it was not until a few years ago that the Board of Trade thought it worth while separately to classify the electrical part of the exports.

It is unfortunate that in the latest developments of engineering the British engineer has scarcely kept pace with the progress of the world. The chief electrical firms of the world are foreign ; and if we examine the development of water-power in places like Peru, we almost invariably find that the machinery used is German. We say this is unfortunate, because electrical engineering is the engineering of the future. If we look at the above statement in detail, we see that in 1910 we exported £1,700,000 worth of rail locomotives, £460,000 worth of road locomotives, and £1,244,000 worth of agricultural motors.

All these appliances in the time to come will be electrical ; and it is highly desirable, therefore, that a nation which depends so greatly upon foreign commerce should be prepared to meet changes which are so near at hand. Th[illegible]

same might be said with truth of a great part of the remaining engines and machinery in the non-electrical part of the above list.

In the meantime, it is notable how strong a position is held in the world by the British textile machinists. We see the United Kingdom exporting nearly £8,000,000 worth of textile machinery in a single year, and countries like the United States, Germany, Russia, France, and India buying from us each about one million pound's worth of textile machinery per annum.

Special considerations attach to commerce in machinery, which are worth careful consideration. A nation which attains eminence in the textile trade obviously does so because of invention and skill applied to textile machinery and its improvement. The United Kingdom experiences a curious contest of interests in the matter of the textile trade.

At one and the same time she seeks to maintain and increase her exports of cotton, woollen, and other yarns and fabrics, and to export the specialised machinery which is the secret of the successful production of yarns and fabrics We are, as it were, selling at one and the same time the flowers and the seed from which to produce the flowers. The sale to five countries in a year of about one million pounds' worth each of textile machinery means in one sense the furnishing of other countries with the means to produce textiles instead of buying them from our mills, and also, of course, the supplying to our competitors of the means of competition with ourselves in neutral markets. It is a remarkable contest of forces, which may be observed but cannot very well be remedied. It is quite impossible to forbid the exportation of machinery, or to prevent one set of manufacturers in the nation from being at cross purposes with another set.

It is not generally realised what an enormous part has been played by this country in furnishing the world with the means of doing modern work. There is no country, new or old, which has not benefited by our exports of the kind outlined above. We have been able to name in the statement a few of the chief buyers, but the true picture is of a world which, in its every part, has been worked for by the British engineer not only in the present, but in the past, with a remarkable assiduity. Here is a statement of the British exports of machinery between the years 1850 and 1911.

UNITED KINGDOM EXPORTS OF ENGINES AND MACHINERY FROM 1850 TO 1910

Year	£	Year	£
1850	1,000,000	1885	11,100,000
1855	2,200,000	1890	16,400,000
1860	3,800,000	1895	16,500,000
1865	5,200,000	1900	20,200,000
1870	5,300,000	1905	24,900,000
1875	9,100,000	1910	34,000,000
1880	9,300,000	1911	36,500,000

In the last sixty years the United Kingdom has supplied the world at large with over seven hundred million pounds' worth of machinery. The greater part of that machinery is still in existence, producing goods and carrying goods, and actuating other machinery, native or foreign, to produce goods. Moreover, the machines sent out have been copied and multiplied, and in some cases improved upon. It is fructifying work of a remarkable character.

In our turn, we have profited, if not to so great an extent, by the work of foreign engineers. As will be gathered from the table on page 2674, we now import about £3,500,000 worth of machinery per annum. The importation of this machinery, which is usually of a special kind, is of assistance to our work, and operates to strengthen our industrial position. We see foreign nations repaying in part the debt which they owe to British engineers. A conspicuous instance is the boot and shoe trade, which we have entirely remodelled during the last few years with American machinery and American patents.

Foreign competition in machinery is a growing factor in trade. The German trade returns for 1911 give the following facts, which show how considerably Germany is increasing her machinery exports.

GERMAN EXPORTS OF MACHINERY IN 1911

	£
Steam locomotives	3,600,000
Sewing-machines	2,600,000
Finishing machines	480,000
Steam-engines, dynamos, etc.	750,000
Metal-working machines	3,000,000
Total, above and other machinery	27,270,000
Cycles and parts	4,000,000
	£31,270,000

Germany is thus closely rivalling us in exports of machinery of a general character, while in exports of electrical machinery she has outrivalled us.

The Americans, of course, have great ingenuity, and with their fine resources in iron and steel it is not surprising that they also are largely exporting many kinds of machinery. In 1911 the export of machinery

by the United States reached a total of £26,554,000. American Trade Returns show how varied are the constituents of this total.

UNITED STATES EXPORTS OF MACHINERY IN 1911

	£
Adding-machines	200,000
Brewing machinery	50,000
Cash registers	740,000
Electrical machinery	1,870,000
Laundry machinery	260,000
Metal-working machinery	2,150,000
Mining machinery	1,400,000
Printing-presses	550,000
Pumping machinery	760,000
Refrigerating machinery	140,000
Sewing-machines	1,900,000
Shoe machinery	370,000
Electric locomotives	14,000
Internal combustion engines	760,000
Steam locomotives	840,000
Marine, stationary, and traction engines, etc.	1,900,000
Sugar machinery	550,000
Typewriters	2,200,000
Windmills	400,000
Wood-working machinery	400,000
Miscellaneous machines	5,000,000
Motor-cars	3,900,000
Cycles	200,000
	£26,554,000

The outstanding feature about commerce in machinery is the same as we noticed in considering iron and steel. German and American competition is growing rapidly, and the British trader needs a greater efficiency than in the old days, when he had things very much his own way. Against increased competition has, however, to be put the not less important and very cheerful consideration that the increased competition is exercised in a world which buys very much more largely than in the days before the rise of Germany and America. There is no reason to believe, therefore, that British power to maintain exports need decline. We are entitled to hope that the necessity for more strenuous endeavour which is revealed by the currents of our time will not fail to evoke from natural aptitude such a response as will keep the United Kingdom amongst the first flight of the world's suppliers.

Amongst the minor miscellaneous items in the trade returns, which count for little in the aggregate, but which have a great significance for the future, is the beginning of the record of a commerce in aeroplanes. The entry heading "Aeroplanes, Airships, Balloons and Parts Thereof" first appeared in the Custom House returns in 1910, and the following figures have been recorded.

BRITISH TRADE IN AEROPLANES, AIRSHIPS, AND BALLOONS

	1910	1911
	£	
Imports	56,206	44,430
Re-exports of imports	12,197	10,022
Net imports for home use	44,009	34,408
Exports of British make	15,486	18,473

These interesting figures are of deep interest, as the first visible traces made by the new engineering upon our commercial records. It is unfortunate that even in these early days they are not bigger. The British industry is very small, and not to be compared with that of the Continent of Europe; and the net importation in 1911 of only £34,408 worth under the general heading of aerial vessels of all sorts, including parts, does not say very much for the enterprise yet exhibited by British airmen or the British War Office or Admiralty.

Returning to the table of Metal Manufactures on page 2674, the minor items may be briefly surveyed.

As to "New Ships," it is a pleasure to record that British shipyards have still no competition to encounter in the home market, while, taking the world's ships as a whole, they turn out something like two out of every three tons of shipping built in all the world. It is almost impossible to believe that our existing degree of supremacy in this regard can be indefinitely maintained, for other nations, and notably the United States of America, possess natural facilities for shipbuilding which must, sooner or later, be developed. Nevertheless, the carrying of men and goods on the great seas is an ever-expanding industry, and the call for ships may easily reach a point at which it will sustain in each of many countries a number of shipyards such as we now possess, and keep them all hard at work. The degree of our supremacy may pass; the actual quantity of work may yet increase considerably.

The item "Electrical Goods" is not so creditable, and suffers from that neglect of the new engineering to which we have already referred. There is fierce competition in cutlery, hardware, implements and instruments, as the figures sufficiently show, imports being £4,000,000, and exports nearly £6,500,000. The item "Other Metals" is largely concerned with crude metals, as well as with manufactures properly so-called; and by far the greater part of the imports, which it will be seen are worth over seventeen million pounds, consists of our indispensable imports of

copper, zinc, lead, tin, mercury, etc., of which we have such poor native supplies.

We next turn to the other great branch of our commerce, that in textiles. As we saw in the table on page 2673, the net imports of these in 1910 were worth £37,100,000, while the exports of British make were worth as much as the enormous aggregate of £166,900,000. The chief items composing these major parts of our external trade are as follow.

COMMERCE IN TEXTILES IN 1910

Textiles: Yarn and Fabrics	Imports: Gross	Imports: Net, after deducting Imports Re-exported	Exports
	£	£	£
Cotton ..	10,875,000	8,500,000	105,916,000
Wool ..	9,599,000	8,418,000	37,524,000
Silk	13,521,000	11,555,000	2,277,000
Other textiles ..	8,056,000	5,370,000	13,484,000
Apparel ..	4,433,000	3,214,000	7,687,000
Total ..	£46,484,000	£37,057,000	£166,888,000

In previous chapters we considered the two staples cotton and wool in detail, and we see them here in due perspective with the remainder of our commerce in textiles. In regard to silk, we have one of the few trades of great importance in which our imports exceed our exports. The rich British market absorbs nearly twelve million pounds' worth of foreign silk-stuffs every year. It is noticeable, however, that there is a diminution in the consumption of imported silk, and that our exports show signs of increasing. In 1900 the net imports of silks were worth nearly £13,400,000, whereas in 1910 they were worth £11,500,000. It appears that the British manufacturer is increasing his sales in the home market and displacing imports. No one can have failed to observe the beautiful silken products of British manufacture which are now exhibited by high-class firms, such as Messrs. Liberty, in the West End of London.

Our statement shows that a considerable quantity of textiles is dealt in in the shape of ready-made clothing. The exports under this head are now worth nearly eight millions a year (excluding boots and hats; the Board of Trade figure for apparel in 1910 is £12,700,000, but this includes boots and hats). There is also, it will be seen, a large importation of apparel.

Under " Other Textiles," linen and jute have chiefly to be noticed. The British linen trade is of very great importance; its exports rank third amongst our textile shipments. We import very large quantities of flax from Russia and other countries. In 1910 our imports of dressed and undressed flax were valued at about £3,100,000. In addition, we import a considerable quantity of yarn. The healthy state of the industry will be gathered from the following record, each of the three years named being good years of trade.

BRITISH COMMERCE IN LINEN YARN AND LINEN GOODS

Year	Linen Yarn: Imports for Home Use	Linen Yarn: Exports of British Make	Linen Goods: Imports for Home Use	Linen Goods: Exports of British Make
1900..	914,000	934,000	550,000	5,225,000
1907..	785,000	1,243,000	783,000	7,346,000
1910..	1,051,000	1,197,000	1,002,000	8,281,000

With an exportation of yarn and goods worth the greater part of ten million pounds a year, our linen industry is no bad third amongst our textiles.

Jute comes next in importance, and has, indeed, an exportation very much the same in value as that of the silk industry, but it is a noticeable fact that, while our silk exports appear to be increasing, our jute exports seem to be decreasing. The facts of the case are as follow.

COMMERCE IN JUTE MANUFACTURES

Year	Imports for Home Use	Exports of British Make
	£	£
1900	566,000	2,431,000
1907	784,000	4,109,000
1910	829,000	2,215,000

It will be seen that declining exports are in this instance accompanied by increasing imports. This case is of peculiar interest, because our competitor is British India. India is the main source of the raw material. The trade is not of a very high character; and as it does not call for any great skill, its decline need not be a subject of very much regret from a national point of view, although it is impossible to forget the interests of Dundee, where it is chiefly carried on. It is to be feared that the Indian competition is only too likely to increase, as the coarse industry naturally gravitates to the source of the cheap material.

We have thus reviewed the main constituents of our import and export trade in manufactures. There still remain to be considered the exceedingly important, if comparatively smaller, trades which form the rest of our commerce, and these are reviewed in the succeeding chapter.

PROGRESS

Reproduced by
permission of
Frederick Hollyer

By
G. F. WATTS

SUCCESSES OF DEMOCRACY

The Moral Gains that Have Come to the World Through Democratic Development

GREAT PROBLEMS THAT CONFRONT IT

THE reader who has followed our discussion of the causes of unrest in the modern labour world, and the difficulties and dangers of the poverty that exists outside the fully organised trade unions, may be impelled to ask the broad question whether, on the whole, the growth of democracy, as seen in the chief industrial nations, is a failure or a success. For good or for ill the progress of the democratic movement is one of the supreme spectacles of recent history. Only one or two other spectacles can be brought into comparison with it. One is the marvellous new command of natural power usable for work which makes man's mere physical labour begin to look paltry, and which has increased enormously the general wealth of the world. This phenomenon unquestionably is starting mankind on a new era. Another spectacle is the stupendous and continuous sacrifice made by all nations in preparation for war. Emancipation from tyranny is already here; emancipation from the more deadening forms of toil seems near at hand; emancipation from human jealousies and hatreds appears to be almost as far off as ever. Triumphant democracy, triumphant science, triumphant militarism, are the world's great spectacles in politics, in economics, and in morals. How a triumphant democracy will reap the harvests of triumphant science, and solve the problem of rampant militarism, are secrets of the future, but we suggest that its successes up to the present are a hopeful augury.

One hundred and fifty years ago there was no genuine democracy in the world. Now there is democratic rule wherever the influence of the Anglo-Saxon and French races extend, and where there is also a white population. Throughout the British Empire, including India, the spirit of government is essentially democratic. The British Colonies provide the first line of the forward movement. In the United States, where modern democracy began, it has never weakened in theory, however faulty it may have been in practice. France has had a purely democratic government for more than forty years. Germany, too, is democratic at heart, if we may judge by her finely organised local government and her wise social legislation. Italy is democratic; Austria-Hungary not far from freedom; and all the smaller countries of Europe—Switzerland, Holland, Belgium, Denmark, Norway, Sweden, Portugal, Greece—register in legislation and administration the will of their peoples. The Far East unexpectedly makes slow and painful efforts to establish a democracy; and even Russia is not wholly without hope, though often disappointed bitterly. The change throughout the world in one hundred and fifty years is almost unbelievable.

And the greater part of the change has come, even in our own country, within living memory. England could not be said to be really democratic until the extension of the household franchise to the counties in 1884; and still there are large sections of the population who do not realise that the State is a democracy of which they are trustees. In rural districts and in ancient towns tradition wanes but slowly, and the idea of democratic possibilities has little stimulating power. The great territorial families retain much of their dominating influence over many a country-side, and that, too, by methods of personal interest and kindness that must command the respect of the onlooker. In the slum quarters of the large cities poverty blots out public feeling; while an admiring recollection of old-time corruption still poisons some of the smaller, and seemingly

most respectable, boroughs. With these limitations plainly observable, it must be admitted that even in England, which is the model for free Governments, democracy is a latent possibility rather than a fully organised actuality, though as a pervasive influence it is here, and has already displayed clearly marked tendencies that call for our study.

The Democracy Not Yet Conscious of Itself and Its Political Power

The sections of society that were "the ruling classes" eighty years ago fully realise now that the genuine power in the State belongs to the mass of the people, and that their own rôle is to persuade and not to rule, or to persuade and so to rule. Hence the activity in forming associations for the use of social influences in politics. Society even is ready to offer friendly co-operative organisation to its own servants to keep them in line with its wishes; and whole sections of the least conscious parts of the democracy are immensely pleased at being flattered and cajoled and wooed. They value greatly the fact that people whom they regard as very superior ask them to give their vote in a certain way. They value this sense of having something to bestow far more than they value the possible influence of the vote itself. The political value of the vote is as the small dust of the balance compared with the fact that somebody of standing canvassed them and somebody else fetched them to the poll in his motor-car. While such feelings as these exist—not predominantly, but widely—the democracy cannot be said to be conscious of itself. It has only felt here and there a shaping impulse towards concentration and organisation.

The Divisions which Prevent the Democracy from Showing Its Full Strength

Take the section of it known as the working classes, and notice how it is split up. In every constituency—even among the miners, who are by far the best organised and most homogeneous group of workers—there are Liberals; there are Labour men who are not Liberal nor yet Socialists; there are Socialists; and there are Conservatives. Thus we have four distinct groups who may become divided in their support of political candidates and in their reading of political aims. But whenever they are fairly united, and carry with them the other members of local society in general agreement with their views, the effect is overwhelming, and democracy triumphant becomes a fact to which public opinion, Parliament, and King bow a polite head.

As a theory, democracy rules all the while; as a fact, it rules whenever it cares to do so and organises itself for the purpose; and in Great Britain the organisation can be swiftly effective, and express itself in tones of command in a few casual elections. It is rather curiously true that in America, the land of liberty, democratic opinion has not the same ready form of expression. It is strangled by the very elaboration of the arrangements made to keep a free country free. However strong may be public sentiment against abuses that manifestly injure the State, the way to reform is far longer and more roundabout than in Great Britain, where a majority of five thousand in three or four successive by-elections would do anything with Commons, Lords, or King. Everywhere except, perhaps, in Germany and Russia the people can rule if they will; and in Great Britain, notwithstanding our sacred traditions, they can rule quickly. Democracy is triumphant, but it only knows it in a subconscious way, and rarely shows it, so that we can best see the potentiality of its rule by noticing the efforts made on all hands for its conciliation.

The Acceptance of Democratic Rule Without Signs of Public Distrust

The democracy reigns in fact; we all admit it, and yet there is the significant outcome that nobody is seriously afraid, or has any substantial mistrust. That result may serve as an introduction to our enumeration of some of the successes of democracy. It is a rather curious result, inasmuch as many people are very timid where the public *en masse* are concerned. They fear they know not what. That may be seen in quiet streets when strikes are prevalent. Though there is absolute peacefulness, and the visitor might be unaware that there was a strike, some men will come home every night from out-of-town business because they do not like to leave their families alone; others will talk of planking up their windows, and Watch Committees will grow restless about police reserves and possible soldiers when there is not the faintest likelihood of trouble. A vague knowledge of French revolutions sends the faintness of cowardice into the hearts of the timid. But the steady and permanent reign of democracy has brought no tangible fear, except, perchance, as an occasional "wild surmise" in the heart of a retired lady here and there Why is it

that no one believes anything untoward will happen from the rule of the people—at any rate, as long as the multitude are fed ?

Well, the public cannot but see that changes are evolutionary and inevitable, under the operation of laws we cannot control, and that we cannot even discover with certainty; that these changes come more slowly than the timid had feared; that they are not so bad after all when we are familiar with them; and that, on the whole, we are no worse off, but perhaps better off. In short, democratic government in action is seen to be not unreasonable.

The Desire for Education a Sign of Democratic Stability

That is the negative view of the success of democracy. We wish to add to it proofs of its positive success, and, indeed, to suggest that while its push for power, and the shows of power—the coveted reward of most forms of government—have been inconspicuous, the moral gain to the world has been enormous, and that the democracy is vindicating itself on the highest platform of human endeavour.

For example, there has been a very strong determination on the part of the active working-class elements in the democracy to secure education at any cost, and so, incidentally, make themselves worthy of a place in the State government, as citizens and voters. A good deal may be said in opposition to the view that the working classes wish for education. It may be pointed out that there is a considerable residuum of the population that cares nothing for schooling, and must have its children dragooned by the attendance officers. Of course, there will always be a certain proportion of the utterly careless who must be directed, cared for, and, when necessary, coerced; but, in the case of education, even in England, where education is less valued than in any other advanced country in the world, the number of the careless among the poor is not large proportionately. Indeed, an exaggerated belief in education is often pathetic among the poorest, particularly when they have felt the need of education themselves, and have realised how they have been held back throughout life by their deficiencies.

The Undercurrent of Middle-Class Hostility to Popular Education

It is quite true that there is in England almost a dislike and a distrust of education through a certain middle-class stratum, particularly of women. They think it will diminish the number of girls available as servants. They think the girls who are servants will know too much, and will not be sufficiently obedient and unquestioning. They think it will bring poor people's children into competition with their own, and may even share the prizes of life between the offspring of the different social grades. A number of more or less clearly shaped thoughts of this kind create an atmosphere of distrust of popular education; and in that atmosphere thrive all sorts of rumours to the detriment of the education that is being given. Thus, tens of thousands of people believe that children in the elementary schools are taught to play the piano, to make meringues, to paint pictures, and to do all kinds of foolish and impractical things. Nothing of the kind occurs, but the detesters of popular education will never believe that such misplaced effort is non-existent, any more than rural Russians will give up the idea that Jews sacrifice little Christian children as a part of their religious formalities. Whereas, in the United States, there is a universal belief in education, extending to the children themselves, and causing them to take eager advantage from the schools within their reach, in England the social tone—at any rate, in the middle classes—is often persistently and bitterly hostile to education for others, if we may accept the spontaneous talk of the tea-table as any guide.

Public Education as an Example of a Sound Democratic Movement

And yet education has progressed wonderfully in England. It is in advance of Ireland, has almost reached the state of Wales, and is in pursuit of Scotland. How has this come about ? The answer is that it has come because of the fixed determination of the democracy to have education, throughout its whole range, everywhere available. That has been the driving force that has placed a good elementary school within reach of every child, a secondary school within reach of all who are clever enough to profit by more advanced education, and has made a university course almost as possible as in Germany, or Scotland, or the United States.

And here we may pause to say what we are meaning by the word "democracy." We do not mean the working class, but the whole body of citizens—all who go to form a State in which all are included. Predominantly this must be the working class, because they are by far the most numerous

section of the public, if it is to be sectionalised at all; and a policy cannot be called democratic unless it has the power of the intelligent masses behind it.

Probably no question enables us to see more clearly what a democracy is than the question of education. In it we see a great body of vigorous opinion, recruited from all classes, moving the inert mass of the unthinking, and establishing great ameliorative schemes. Always, even when popular education began in the 'sixties of the nineteenth century, a slow and silent body were stolidly indifferent, and the stingy and timid more or less hostile, but a strong combination of sturdy opinion formed a central corps for public-spirited action that swept the rest steadily along. With it, of course, went the theorisers, the educators, the philosophers, the dreamers; with it, too, went the far-sighted industrial organisers, the manufacturers who knew that they would need in the future well-educated workers, as science placed more of Nature's powers under man's control. But all the while the main body who marched under the flag of education were the hard-headed, intelligent, thrifty workmen, who saw through education greater efficiency for themselves and a new vista for their children.

Working-Class Belief in Education and Interest in Civic Life

Never yet has there been any advance proposed in education that has not had the enthusiastic support of the whole body of organised labour opinion. Although the retention of children at school until they were twelve, thirteen, fourteen, has been successively debated, and each extra year at school meant a lessening of the potential earnings of the family, organised working-class opinion, concentrated for public use, has always kept pace with educational theory. The employers may have faltered: the backbone of the democracy remained firm. Through education the pick of the working class saw a way out from the extremity of manual labour. They saw their children, in imagination, taking rank with the brightest intellects. And however its views were arrived at, the broad fact remains that the democracy has believed in education, and has sought eagerly to educate itself. It has succeeded, too, in many respects, for today, without a shadow of doubt, it is the mass of skilled workmen who, as regards civic knowledge and political principles, are by far the best educated members of the community. If anyone doubts it, he should find opportunities for comparing serious discussion in, say, a good-class London club, a railway carriage freighted with an average of the English middle-class, and a shop in some great works at breakfast-time. He would soon discover not only where political acumen is to be found, but information and ideas. The democracy has been laying firm foundations in its own education.

The Wise Use of Economic Gains by the Democracy

Again, the democracy has registered a success in the form in which it has taken whatever material rewards have accrued to it from the improvements made through extended scientific knowledge. It may be argued that the gains to the mass of the working class from a hundred years of science have not been considerable. That is partly true of the last dozen years, owing to the rise in the price of commodities more than balancing better wages, but, looked at broadly, the gain has been great, and has been well used. If it be said that popular amusements are frivolous, we can ask in reply where are the brutal sports so common in the days of our grandfathers? In the days when a considerable proportion of "the common people" were dependent, or parasitic, their tastes were coarse and animal. Part of the modern social movement has been a fight for leisure, and that leisure, on the whole, has been very well used. The power of rational enjoyment has been expanding—perhaps even beyond the means of gratifying it. Everyone now wishes to travel, to see the world, to exhibit in one way or another evidences of taste. Though much remains to be achieved in purification of pleasure and in the spread of more sensitive manners, a good deal of the grossness of English life has been sloughed away, and a much higher general level of wise living is reached.

The Type of the British Democratic Leader as Evidence of Good Sense

The age of democracy, in short, is an age in which leisure and spare money are spent far more morally and tastefully than heretofore. Though many still tramp through the mire, the march, on the whole, is towards the heights.

Because these things are observed, the general confidence in the new democratic forms of government is deep and strong. A further cause of confidence is found not only in the balance with which the working classes divide their support between now this and now that political party,

THE APOTHEOSIS OF THE COMMONWEALTH

"THE TRIUMPH OF THE REPUBLIC," A SYMBOLICAL PICTURE BY LÉON GLAIZE

according to the exigencies of the moment, but also in the judgment displayed by the substantial trades unions in choosing their leaders. The type of man elected, for example, to the British Parliament by constituencies where organised Labour holds the political power has been such as commands the nation's sincere respect. Whether judged by character, sterling sense, ability, or knowledge of the essential life of the nation, these democrats have reached a high level of worth. It may be said that there are signs of some deterioration in this respect, and that wilder spirits, whose talk is inflammatory rather than reasoned, are gaining in the competition against more sober judgment, but that view is not supported by a count of the men who actually reach the House of Commons. A sturdy, inflexible good sense seems to be the central feature of working-class character when it is judged, over considerable periods, by its most constantly recurring traits. Unquestionably one of the successes of democracy has been the general practicalness of the ideals adopted, and the power of applying the touchstone of character to those who have been chosen as its representatives.

The Conception of the State, Even Among Socialists, Opposed to Class Warfare

And not only has conspicuous moderation been shown in collective action, but, idealistically, the lower-middle grades of the democracy—if we may so designate the working classes who are above the ranks of the casually employed—have shown a fine grasp of broad political conceptions. In this respect they are far ahead of the classes that are often described as above them. Take, as an illustration, the most extreme section that finds representation in Parliament—the avowed Socialists. Though wild words are let loose now and again by the wilder spirits, the serious, fully considered opinion of the party, expressed through all its responsible men, is against class warfare, and against appeals to the cupidity of the populace. It builds, in imagination, an all-inclusive State, where every type of intelligence and skill will have full play, and where organised capital, however owned, and brains, wherever found, will work co-operatively with less skilled labour. When a theory of class exploitation is introduced—as in Syndicalism—it is the Socialists who step forward to prove its unsoundness, because it is contrary to their broader conception of the State; and so from the very midst of Socialism itself there emerges an influence that is in a large degree conservative. Indeed, in Great Britain every form of organised public opinion, sooner or later, in spite of impatience against the delay of plainly needed reform, assumes a practical shape, strives to be workable, and shrinks from whatever is loosely and irresponsibly destructive. One cannot watch the instinctive action of democracy over a reasonably extended period without feeling that, somehow or other, because of some inherent steadying influence that has never been isolated and analysed, the final resultant action of democracy—at any rate, in Anglo-Saxon lands—is at once more progressive and more conservative, fairer, sounder, and wiser than the action of any single section of the community would be, even if the section were comprised of all the philosophers. Thus democracy is justified by its practical results.

The Moral Tone of Public Life Raised Under Democratic Influences

But the successes of democracy are far greater than those measurable by negative terms. It has done immensely more than avoid mistakes. It has brought a new and finer moral tone into public life. It has so far made politics religious as to satisfy the altruistic aspirations of millions of men apart from the Churches, and to advance the claim that pure religion and undefiled, the religion of humanity, is often to be found not less genuinely in movements where religion is seldom named than in the places where it is professionally advocated, and socially patronised and safeguarded. Wherever the Labour element in the democracy has gathered strength and independence it has unselfishly adopted a policy of "helping the bottom dog." It has urged unceasingly the bettering of the conditions of those who are so low that they have lost all care for their own improvement.

The Persistent Democratic Battle on Behalf of the Worst-Paid Labour

Who are the people who feel most imperatively the need for dealing with the idler, the vicious, the debased? Besides a few philanthropists and philosophers and publicists, it is the skilled working class that sees the dangers and needs of the unskilled, the hopelessly weltering lost of the slums. They it is who say most earnestly: "You shall have your surroundings bettered; your tastes raised, your power for harm nullified; you shall be educated and taught self-respect, and regularised in your work, whether you wish it or not."

The battle of the poor and the outcast from our economic system is being fought with much earnestness and concentration by the best working-class elements in the democracy and their allies; and it is true in some cases that the exponents of the new democratic spirit offer a more satisfying religious aim to many sympathetic men than these men obtain through the routine of the Churches.

The Permanence of Moral Fervour Established in Public Life by the Democratic Spirit

People who look at democratic tendencies from the outside and afar off sometimes affect to be shocked, frightened, despairing, and to regard them as atheistical and demoralising; but those who know the spirit of the movement better are aware that it is pre-eminently moral, idealistic, passionately helpful, and believes in its own heart of hearts it is carrying forward the true spirit of Christianity.

However limited this view may be of the realm of religion, there can be no doubt that the democratic tendencies of the age—the democratic potentiality, and all the hopes it has raised—have infused a new spirit into politics. Democracy has brought into Parliament as a permanency the kind of moral fervour that only existed in public life in the past when some question of special poignancy was being discussed, as, for example, slavery in the days of Clarkson, and Corn Law repeal in the days of Cobden. Such questions temporarily placed politics on a new plane. Now the lasting "condition of the poor" question, approached in a spirit of sensitive but reasoning humanity, permeated by a passion of unselfish helpfulness—because many men in public life know the realities of the life of the poor from the inside—is giving democratic endeavour a lofty moral, and indeed religious as well as practical aim, beside which the exigencies of party warfare and wiles of personal ambition appear cheap and paltry. The democracy has raised the moral tone of politics, and has not —whatever we may think or say in times of passion—lowered its manners.

The Burden of Preparation for Wars that Would Stagger Humanity

But the moral triumph of democracy, though visible in its self-restraint, and still more in its desire to help the weaklings and least fortunate in the economic State, is most clearly seen in the stimulus it has given to the sense of universal brotherhood. Never since the world began has the claim that "Men should brothers be, and form one family, the wide world o'er," seemed such a stupendous irony as now, and never has the hope seemed nearer realisation. We see the most wonderful efforts of human organisation, invention, and sacrifice concentrated on preparations to kill and destroy in the most wholesale way.

Whenever ingenuity makes a further advance in science and industry, the new step is hailed as a fresh preparation for war. Methods of flying are gradually improved, at a great cost in life and thought and money, but five people out of six instinctively regard these gains in knowledge and skill as introductions to human butchery. The wealth that is needed for the relief of social evils—to spread health and gentleness and plenty among our fellows—is used, after infinite labour, to make engines of death that become out of date almost at the moment they are made. The nations groan, that untold millions may be squandered on ships which are old and decrepit—according to the experts—before the public that paid for them has had time to learn their names. Great nations drill by the million, half in fear, inside their frontier lines; and everyone trembles lest some inadvertent foolishness, or wave of mistaken passion, should precipitate a conflict at which humanity would stand aghast.

The Brotherhood of Man a Democratic Sentiment and the World's Hope

Who is there to make a stand against this insane, unholy, and preposterous state of affairs? Not the kings of the earth. They dislike war, for it brings that "fear of change" which "perplexes monarchs," but they accept it as belonging to a scheme of things which includes their own existence as kings in a state of pomp that is always semi-military. Statesmen, "the governing classes," as the world has known them, and the professional classes, who now so largely govern us, have never taken any steps to abate the war fever that is always incipient, more or less, everywhere. Indeed, by their general sentiment towards national prejudice, the middle classes that are not trading with foreign countries partly palliate war by their attitude towards it, in thought and talk, and partly encourage it as an outlet for jealous feelings they have been carefully nursing in the name of patriotism. Even the Church, in its many forms, tolerates war as a sort of conventional necessity. And so the danger continues, or perhaps even grows.

Always there has been a band of clear-thinking people who have seen war's horror

in its naked form, and refused to be magnetised by it into a state of coma, but they have been scattered over the earth—a remnant. The rest have acted as if they believed that the right answer to the poet's question: "Shall crime bring crime for ever?" is a regretful "Yes." Who is there to reply with an emphatic "No"? One looks in vain over the world for the protesters if they are not to be found in the democracy of each nation.

And, indeed, there are encouraging signs that what the kings and the oligarchies and the governing classes and the highly elaborated Churches have never done, nor ever looked like doing, will be done ere long by the enlightened and emancipated democracies of the chief nations. Not only do the working-class democrats declare the solidarity of the workers, but also of humanity. The sympathy between men living under like conditions, and fighting the same social battles, in a kind of war that overfloods the barriers of nations, tends to obliterate carefully fostered national jealousies; and, wherever and whenever the nations meet on a free, democratic footing, they ask each other: "Why should we be assuming a quarrel with each other when our interests are identical, and are only served by peace and goodwill?" It is the democratic element in society today that is spontaneously in favour of human brotherhood and peace; and that, indeed, on the international as well as local economic scale, is rescuing from its ecclesiastical hiding-places the original gospel of Christ.

PEACE WITH WINGS AND HORSES—THE QUADRIGA ABOVE THE ARCH ON CONSTITUTION HILL

If the advent of democracy is doing this, and leading mankind back from the madness of war and strife, who will deny that it is moving forward towards a success unexampled in the civic world, and only paralleled in the dreams of the good? It may be that again and yet again the democracies of the modern world will be blinded and inflamed by passion and local prejudice, and will play into the hands of those who would exploit them for the sake of selfishness and ambition, but the augury, as far as it has declared itself, is more hopeful than under any other form of government the world has known.

We have suggested that the three most stupendous spectacles of our age are the triumph, during the last hundred and fifty years, and more particularly during the last five-and-twenty years, of democracy; the triumph of science, which will enable the earth to bring forth abundant riches for all men, with a great lessening of wearing labour; and the strange spectacle of mankind straining to store for destruction its energies of hate. The final success or failure of democracy will depend upon its solution of the problems inherent in the two other spectacles. How will the ample spoils of science be distributed justly among all men? How will the incubus and enormity of war be sent to the region of bad dreams, where the world's outgrown errors remain only to shame us? If democracy can solve these problems, it will have crowned its already considerable success. May it not be said, with some hope of accomplishment, that the greatest need of the people of each of the leading nations is that they shall be educated up to the level of sympathy with other peoples? If they once reached that condition, not only would illfeeling disappear, but positive goodwill would take its place. An encouraging feature of modern international relationships has been the rapidity with which animosities, widespread and apparently deep-seated, have died down. Between Germany and France no rancour remains; Russia and Great Britain, once enemies, are now friends. The swift spread of knowledge makes possible those national understandings through which lies the highway to peace.

MORE NEW FOUNDATIONS

The Latest Investigations of American Eugenists, Showing how Hereditary Transmissions will be Finally Understood

INFERENCES FROM A STUDY OF EPILEPSY

Just in time for its chronological place in this section, there has reached the writer a mass of new matter published by the American Eugenics Record Office, and bringing the development of eugenic knowledge down to the end of the first half of the year 1912. None of this material has yet been studied or discussed in this country, though in due course it will require to be recognised as an advance on the best we have as yet attained, and it is a privilege and a responsibility to deal with it here.

All the world of life is one, and it is remarkable to observe that this new work might almost equally well be referred for discussion under "Life," or "Man," or "Health," for it deals with man, especially in relation to certain aspects of health, and it illustrates and extends our knowledge of the laws of genetics, which are an essential part of the study of life; but we shall deal with it here, first because the work was done and has been published in the service of eugenics, and second because it is of more vital and immediate moment for the Eugenist than the biologist, anthropologist, or hygienist, though all these are closely concerned with it.

The new work follows very closely upon the lines of that which has been already discussed, and deals in the main with abnormal and morbid characteristics, so that we might have postponed its study until we came to the problems of negative eugenics. But any such delay would be regrettable at the present time, when public and political attention is being so largely directed to the very questions which the American students have lately studied to such purpose; and we have further to learn that these very methods, which have proved themselves so successful in the study of the abnormal and undesirable, will alone avail in that exact study of the normal and desirable characters upon which alone we can found a positive eugenics that results will justify.

It is therefore our duty to study and duly weigh the results and the suggestions embodied in Bulletins 4, 5, and 6, issued by the American students, in succession to the first three, which we have already considered in careful detail. We have seen that the first of these bulletins placed the study of feeble-mindedness on a new level, by its exact analysis of many genealogies and if the reader should have occasion to compare the results obtained by Dr. Goddard's work with the best knowledge that preceded it, as embodied in the evidence and the report of our own Royal Commission on the Care and Control of the Feeble-Minded, which reported in 1908, he will realise that it would be almost impossible for us to insist too strenuously upon the American advances which we owe simply to the conscientious and skilful application of Mendelian knowledge to these problems. Dr. Goddard showed clearly that along Mendelian lines, and only thus, could we elucidate the genetics of feeble-mindedness. Now, in Bulletin No. 4, by Dr. C. B. Davenport, whose name is already familiar to all students of genetics, and Dr. Weeks, of the New Jersey State Village for Epileptics, we have what is entitled "A First Study of Inheritance in Epilepsy," and is indeed fully worthy of the title, for it demonstrates at once that previous studies of this subject have been too superficial and indiscriminate to count.

Until the American workers began to apply the Mendelian theory and Mendel's method to these human problems, as no students in Europe have yet done, the "method" of studying inheritance in

human defects and diseases has been a very simple one. The present writer has done his share of this kind of thing in past years, and has no prejudice against it when he now points out its defects. What we have done hitherto has been, say in the case of epilepsy, to determine in what proportion of cases an epileptic was known to have epileptic ancestors or other relatives, and then to name the figure obtained as an index of heredity. But we can see at a glance how vague such results must be. If we made our inquiries limited, we should find that perhaps 20 per cent. of our patients had epileptic relatives. But if we asked after remoter as well as nearer relatives, and were not satisfied until we had trustworthy answers, we might find that as many as 75 per cent. of our epileptic patients had epileptic relatives. Thus one observer would state that heredity was responsible for 20 per cent. of cases of epilepsy, and another that it was responsible for 75 per cent. Obviously, such discrepancies were intolerable, and only tended to bring discredit upon the study of the subject as a whole.

The Results of Tracing the Pedigrees of a Village of Epileptics

The American observers have gone to work very differently. Mendel taught us once and for all that only individual analysis of individual pedigrees would reveal any real facts of heredity. Hence these authors have obtained the precise and detailed facts of the pedigrees of inmates of the New Jersey State Village for Epileptics, and they have done so by the use of "field workers," trained for the purpose, which has already been described here, and the introduction of which into eugenic research in this country cannot be much longer delayed. The authors say of their method: "We are convinced that any advance we have been able to make in the difficult subject of inheritance of epilepsy is largely due to it," and their paper bears out their contention to the full. The whole history of science is, of course, the history of a succession of men who taught us, as Bacon said, "How rightly to put the question to Nature." The right method is an "Open, Sesame," and justifies itself everywhere, just as Mendel's is doing now.

This new work is unparalleled in scale and quality. No less than 177 distinct pedigrees were ascertained in detail, and analysed. Not one, of course, deals with less than three generations, few deal with so few, and some deal with as many as six. The Mendelian analysis has been carried to such a point of complexity as could not usefully be discussed here, where, after all, we are primarily concerned with results. Those results are clear enough, and every Eugenist must be deeply grateful for them. In the first place, the relation between feeble mindedness and epilepsy, which has long been vaguely recognised by medical science, has been confirmed and defined.

The Transmission of Epilepsy Proved to be Similar to the Transmission of Feeble-Mindedness

Davenport himself demonstrated, in 1909, the rule which has been so widely quoted since—that two feeble-minded parents *never* produce a normal child. That statement has been re-examined, and the result of detailed inquiry at Vineland is to show that thirty-five matings between feeble-minded persons yielded 142 known offspring, all feeble-minded. And now we come to the parallel and entirely new fact that epilepsy behaves similarly; so that we have to assert the important fact that *when both parents are either epileptic or feeble-minded, all their offspring are so likewise.* Very frequently the offspring may present both defects, so that we see feeble-mindedness and epilepsy to be dependent on the absence of Mendelian "factors" that are very closely akin in their genetic behaviour and consequences and distribution. But whether this demonstration is of more interest to the students of nervous and mental disease or to the Eugenist, upon whom it lays so evident an obligation, it would perhaps be difficult to say.

The Poorhouse Fertility of Defectives Equal in America and England

This new work is on too extensive a scale for us to quote individual pedigrees, but as we pass on we must note one or two points. Thus, the authors publish in full two striking diagrams, dealing with four and five generations respectively, which illustrate what they well call the "poorhouse source of defectives." Of the first, where a large progeny of feeble-minded and epileptic persons descended from a feeble-minded and epileptic woman, who was taken out of the institution with these terrible consequences, the authors say "As a commentary on the condition of an almshouse this chart is eloquent."

The English critic has some grim feeling almost akin to satisfaction when he discovers that even in the progressive United States the conditions of the almshouse and the workhouse still correspond to those of the general workhouse in this country.

where not infrequently you may find three generations of the feeble-minded all living together, grandmother, mother, daughter, all hopeless, all illegitimate, all encouraged and brought into the world in the workhouse infirmary with the kindly aid of the State. Yet, though several years have now passed since the reports of the Royal Commissions on the Poor Law and on the Feeble-Minded, and though the general workhouse is condemned by everybody (including both sections of the Poor Law Commissioners, majority and minority), nothing whatever has been done, and the "poorhouse source of defectives" is now more copiously fertile than ever.

The Hovel-Dwelling a Source of Defectives, Alike in America and England

And to these records may be added that of another pedigree, no less tragic, and, indeed, so abominable that we cannot describe it here, which illustrates what our authors call the "hovel source of defectives." Those who know anything of rural England and its hovels could easily parallel this appalling record. The authors' comment upon the facts, which cannot be discussed here, is as follows: "The empty germ-plasm yields only emptiness. These things were done in a little hut in the woods until it burned down, and now mother and eldest daughter (epileptic, feeble-minded, and criminal), when not in the county gaols or the Monmouth county almshouse, live in a cellar in town. The man is dead, but some of his protoplasm is living and at large." A little further on we come to a pedigree "ending" with five feeble-minded children born to a feeble-minded father and an epileptic mother, and the authors conclude their account of it as follows: "The feeble-minded children are approaching an age when, upon demand of the father, they may be set free on the community to continue the pedigree." Exactly similar is the present state of the law and its consequences in this country.

Insanity and Feeble-Mindedness Not Due to the Same Factors

A further series of pedigrees deals with matings between a feeble-minded or epileptic parent and one who is "insane." The importance of these cases lies in the fact that a definite, small proportion of normal children occur. This strongly points to the conclusion that "insanity and feeble-mindedness are not due to the same missing factors, and so some normal children result." All this is valuable in helping towards that exact analysis of human characteristics upon which alone we can base a sound eugenics. Doctors have long insisted on the very real distinction between feeble-mindedness and insanity, closely though these may often resemble one another. These pedigrees afford strong genetic confirmation of the distinction, as we see when we compare them with the results of mating between *two* feeble-minded or epileptic persons. The invariable absence of any normal children in these latter cases contrasts most strikingly with the presence of a proportion of normal children in the other case, where each parent has a defect, but it is not the same defect, and in a proportion of cases the feeble-minded parent will contribute a germ-cell that remedies the insanity of the insane parent, and the insane parent a germ-cell that remedies the feeble-mindedness of the feeble-minded parent.

A large number of important pedigrees and tables must be passed over here, and we must consider the main conclusions which the authors have reached. They definitely advance our knowledge far beyond anything we might have hoped for regarding one of the commonest and most important of human defects, which is a problem of increasing importance throughout the civilised world, and we shall do well to observe these conclusions with care.

The Discovery that no Epileptics are Born from Entirely Normal Strains

The hereditary character of ordinary epilepsy has been established beyond a doubt. The old contradictory figures of the "index of heredity" in epilepsy are entirely superseded. The authors have found no evidence, throughout this gigantic research, of the occurrence of epilepsy in strains which are devoid of defective germ-plasm. They have many records of epileptic children of two normal parents, as we all have. But they have not contented themselves with the assertion that, in such cases, the epilepsy is not inherited. They have examined the relatives of these normal parents, and have *constantly* found that those relatives include a proportion who are epileptic, feeble-minded, or otherwise nervously affected. The evidence is clear that the normal parents of epileptic children *do not belong to normal strains.* Though they are personally normal, they carry a proportion of defective germ-cells, and this is the key to the fact that some of their children are defective.

Here is a discovery of the first importance, entirely new to science, undiscussed hitherto by Eugenists, to say nothing of legislators,

in this country; and it is one which could never have been obtained without the application to man of the method which Mendel invented for the peas in his monastery garden half a century ago. The present writer, who was the first Eugenist to advocate the necessity of applying Mendelian methods to eugenic problems, hitherto unavailingly so far as official eugenics is concerned in this country, may be excused for feeling some satisfaction at these large and prompt returns for eugenics from the land, not of its birth, but of its adoption.

There is known to medical science something which is called "traumatic epilepsy"—*i.e.*, epilepsy due to a trauma, or injury, as when a child has been struck upon the head. No doubt such epilepsy exists, but the American evidence shows that it must be very rare indeed. The question must, indeed, be answered whether anything identifiable as epilepsy ever occurs except in those who have the tendency thereto. Many children bump their heads, but epilepsy is not the result; and now we begin to see why.

Epilepsy Acquired by Injury not Capable of Being Transmitted

Unfortunately, the students of nervous disease and of heredity have been misled for several decades by the famous experiments of the French physiologist Brown-Séquard, who asserted that when young guinea-pigs were injured they acquired epilepsy, and that this epilepsy was transmitted to their offspring. This has been quoted by countless writers as proof of the "inheritance of acquired characters," and every text-book on heredity and evolution and neurology devotes long discussion to it.

These experiments should be no longer referred to. They were not worth making, and are highly repugnant to our instincts of humanity. Their so-called results were worthless, and have not been obtained by other observers. Guinea-pigs are very liable to epilepsy. We nowadays do not believe that Brown-Séquard really produced epilepsy in his guinea-pigs, and we have definite proof that, in any case, there was no greater occurrence of epilepsy in the offspring of the damaged animals than in those of undamaged "controls." But the importance of "controls," for purposes of comparison, was very inadequately recognised in Brown-Séquard's day. The verdict of our own time, then, most notably confirmed by this new American research, is that true "traumatic epilepsy," not based upon a definite pre-existing tendency, must be exceedingly rare, and that, where it really does occur, there is no reason whatever to suppose that it will be transmitted, any more than if the damage, instead of being done to the skull, had been done to the shin.

Investigation of the Question Whether Alcohol Acts as a Racial Poison

Our authors have had some opportunity, in the course of their research, for examining the proposition, long maintained by the present writer, that alcohol is what he calls a "racial poison." This is a question which falls to be considered much later in this section, and fortunately so, as some important Continental studies on the subject are about to receive publication. But we may properly note what the present research can contribute to this inquiry. The authors rightly say that they have not "sufficient data, nor data of the right sort, to settle this question, but what we have is sufficient to give some support to one hypothesis or the other." The nature of the evidence can readily be stated. The authors have shown how feeble-mindedness and epilepsy occur in certain definite Mendelian proportions in pedigrees which have been properly examined for the purpose. The question therefore arises whether or not those proportions are exceeded in pedigrees where alcoholism comes in as a complication. In other words, if the natural defects of the stock be complicated by the action of alcohol on the germ-cells, which is asserted in the theory of racial poisons, as held by the students of alcoholism, we should find an excessive proportion of defectives in the stocks thus poisoned.

The Greatly Increased Percentage of Defectives from Alcoholic Parents

The authors have carefully examined their records from this point of view. In one table they find a great preponderance of defective offspring—87 per cent., instead of the expected 50 per cent.—and the same is true, in lesser degree, of the second table in which alcoholism occurs as a complication. They therefore say: "We see, accordingly, a constant excess beyond expectation of epileptic and feeble-minded offspring from alcoholic parents. In so far our results support the view that alcoholism, to a certain extent, is a cause of defect, that 10 or 20 per cent. more children in any fraternity are defective than would be were it not for alcohol." They go on to show that these figures are not conclusive, and that more inquiry is needed, opinions in which the present writer heartily concurs, but it is

THE SPONTANEOUS JOY OF LIFE AS IT MIGHT ABOUND UNDER EUGENICAL CONDITIONS

"THE EARTH'S AWAKENING." A CHARMING PICTURE OF SPRING, BY E. A. HORNEL, NOW HANGING IN THE ART GALLERY, DUNDEE

clear to them and to him, and will be so to the reader, that their results are not unworthy of note.

Finally, we may review the principal conclusions which the authors state in their summary. The method of "field-study of epileptic families" and the Mendelian theory account for their success. Epilepsy and feeble-mindedness are closely allied, and each is probably due to the absence of a Mendelian factor—or factors—necessary for normal nervous development.

The Probable Identical Origin of Epilepsy and Feeble-Mindedness

Davenport's rule, found in 1909, regarding the children of two feeble-minded parents, is found to be true for epilepsy. *It is highly probable that feeble-mindedness and epilepsy are two symptoms of one and the same factor defect of the germ-plasm.* According to variations of nurture, surroundings, excitement, education, a host of factors of whose action we know very little, this defect may show itself as feeble-mindedness or as epilepsy, or, in very many instances, as both. But probably these differences are "nurtural," and have their identical and single root in the one "natural" fact of the absence of some Mendelian factor from the germ-plasm. The genetic similarity of feeble-mindedness and epilepsy is thus explained, together with their interchangeableness, their frequent association, and also the overwhelming evidence of doctors, philanthropists, and social reformers that just the same treatment is best for both. Can the reader imagine with what feelings these advances are welcomed by a writer who, little more than a decade ago, accepted the authoritative teaching of his seniors and teachers that "the treatment for epilepsy is large doses of bromide"?

Nervous Conditions Half-Way Between Normality and Defectiveness

Our authors have also reached a conclusion of an entirely novel character, which can only be appreciated by the reader who has followed with sufficient closeness the discussion of modern Mendelian theory in another section of this work. They have gone far to show that a number of minor nervous conditions, such as migraine, chorea (St. Vitus' dance), and extreme nervousness, behave genetically as if they were due to the inheritance of complete normality from one parent and a factor of defect from the other. These persons, so to say, are half-way between "normals" and "defectives," and they may be conveniently called tainted. Let us recall the view of each individual as double, as made by the contribution of factors from two sources—like the drops from the bottles of chemicals in Professor Bateson's simile, described elsewhere—and we then see that these "tainted" individuals, as they may be conveniently called, have had normality added to them from one side, but defect from the other. *They usually carry some wholly defective germ-cells*, for "when such a tainted individual is mated to a defective, about one half of the offspring are defective."

Having reached the conclusions briefly outlined above, what do the authors suggest? The answer is "segregation during the entire reproductive period of epileptics of both sexes." This is, of course, a matter which will have to be discussed here later, but we may properly conclude our discussion of this valuable, laborious, and temperate piece of work by quoting what its authors have to say of the consequences in America of the segregation which they advocate

An Argument from Economy and Public Health for the Segregation of Epileptics

"Such measures would be an expensive burden for the present generation of taxpayers; but if it is ever justifiable to bond a State, it is for such a purpose as this, because inside of ten years the stream of defective children would be almost dry. By twenty years half of the temporary detention sanatoria for defectives could be closed, and by thirty the expense of maintenance would probably be less than it is now. By forty years an institution like that at Skillman (in New Jersey) would probably provide accommodation for all the remaining defectives (now grown quite grey), and in fifty years there would remain only an old man's and old woman's home for such as did not care to leave its shelter to return to their relatives. By this time the State could pay off its bonds from the sale of most of the land reserved for these unfortunates. Of course, through immigration, through trauma (accidental injury), and through the chance union of defective germ-cells of normal persons a thin stream would be maintained, but the State would have control of the situation, and the expense would be ever diminishing instead of, as now, ever increasing."

In Bulletin No. 5, Dr. Rosanoff, aided by Miss Orr, returns to the subject so notably discussed by himself and Miss Cannon in Bulletin No. 3, which we have already studied. That was only a preliminary report, very properly issued directly the

evidence was obtained that "the neuropathic constitution is transmitted by heredity, probably in the manner of a trait, which is, in the Mendelian sense, recessive to the normal condition." To the twelve families first examined, sixty more have now been added, representing two hundred and six different matings, with a total of 1097 offspring. This very large mass of data, to which no past inquiry of the kind bears any comparison whatever, has all been now examined on Mendelian lines, and the authors present a table in which the actual results and numerical expectations of normal and neuropathic, according to Mendelian theory, are compared. Study of the figures shows at once that the correspondence is very close indeed, no more than the customary slight discrepancies being found. In some cases the correspondence between expectation and finding is exact, and in all it is remarkably close; and the authors are plainly entitled to write the following sentence, which they italicise: "It would seem, then, that the fact of the hereditary transmission of the neuropathic constitution as a recessive trait, in accordance with the Mendelian theory, may be regarded as definitely established."

Proofs that Nervous Conditions are Transmitted on Mendelian Lines

This is a result of the highest importance, and one which probably far exceeds the hopes even of the most sanguine advocate of Mendelism in relation to eugenics. When the colour of the eyes, the form and colour of the hair, peculiarities of the lens of the eye, and such characters, were shown to have simple Mendelian foundations in the germplasm, we were impressed and hopeful; but it scarcely was to be believed that nervous conditions, whose external symptoms in psychical behaviour are so extremely complex, should also be traceable, and so soon, to a similar simple and controllable foundation. This is a triumph indeed, which the present writer freely confesses that he had no prospect of being able to record when this section of POPULAR SCIENCE was begun.

But now observe what the authors of this bulletin are able to add, and how it agrees with what we saw in the summary of No. 4. It was there suggested, on very good evidence, that there is a condition half-way between normality and feeble-mindedness or epilepsy, which the authors called "tainted," and there is reason to look upon this "tainted" condition as due to the inheritance of the defect from one parent and of no defect from the other. Thus we can conceive of what appear to be the facts, in Mendelian terms, under three heads. There will be people who have inherited the nervous health factor, so to call it, *from both parents*. In respect of this factor these persons are what may conveniently be called duplex. They are the normal persons —fortunately, of course, the great majority of the community.

The Various Degrees of Neuropathic Taint that May be Inherited

But if one inherits the factor from only one parent, and inherits the absence of it from the other, then one is what Professor Bateson calls "heterozygous" and such persons, heterozygous in respect of this factor, are the "tainted," who are liable to display a wide variety of eccentricities, hysteria, neurasthenia, and so forth, which are often largely controllable, may appear at one period of life and not at another, and may be scarcely observable under very favourable conditions. And thirdly, there are the unfortunate people who, instead of having a "double dose" of this nervous health factor, one from each parent, like ordinary people, or a single dose only, from one parent, like the tainted or "neurotics," have inherited it from neither parent, or have inherited the absence of it from neither parent. These correspond to the feeble-minded and epileptic whom we have lately been studying.

Here we find a striking resemblance, from the Mendelian point of view, between the development of health in the nervous system and the development of colour in the skin.

A Curious Similarity Between Health of the Nerves and the Colour of the Skin

The Mendelians have shown how various factors combine to produce certain results, say in pigmentations; how in the absence of one factor a change ensues, and in the absence of a second as well, yet another form of pigmentation is disclosed; and they have also shown cases where the individual is markedly different according to whether he has a single or a double "dose" of some given factor in his constitution. And now the American students are beginning to show, as the two bulletins now under examination suggest, that, as Dr. Rosanoff says: "It seems necessary to assume that the normal development and function of the nervous system is dependent not upon a single unit determiner—*i.e.*, Mendelian factor—in the germ-plasm, but upon a group of determiners, and that the

number of units lacking from the group determines the special type of defect to be observed clinically."

The charts and tables in this bulletin must here be passed over, and we can deal at once with the authors' conclusions, in so far as they have not been already stated. Those conclusions deal mainly with the incessantly discussed question of the proportion of nervously defective people in a modern community, and of the possible increase of that proportion under contemporary conditions. The evidence and the arguments cannot here be detailed, but they lead the authors, first, to a conclusion which tallies with many preceding estimates —viz., that the proportion of persons in a modern community who suffer from all forms of nervous defect put together may be roughly estimated at between 1·5 and 2 per cent. This is somewhat higher, no doubt, than the estimates made by our own recent Royal Commission, but those estimates were generally recognised by experts as being somewhat too low.

A Startling Suggestion that Nearly One-Third of Mankind Carries a Neuropathic Taint

The second conclusion is no less important in its way, and it has regard to what we can only call a new conception in this branch of knowledge, though it is, of course, a conception as old as the work of Mendel. We now see that there must be a number of people in the community who, "without being actually neuropathic, carry the neuropathic taint from their ancestors, and are capable under certain conditions of transmitting the neuropathic make-up to their progeny." So long as we studied "heredity" in only two generations, of course nothing could be learnt of this question. So long even as we thought that an individual can only inherit and display what its own parents display, we could not reach this new conception. Only the Mendelian ideas of dominance and recessiveness could have enabled us to understand how the individual is one question, and the quality and relative proportions of the germ-cells the individual bears are another question, only to be unravelled by going further back to his ancestry. But the startling and alarming fact that now presents itself is the proportion of such persons at which these authors arrive. They say: "Our data seem to show that no less than 31·6 per cent. of the general population carry the neuropathic taint!" Their surprise is natural, and will be shared by their readers, yet the evidence is very good so far as it goes, and on consideration the figure they reach becomes less surprising than at first. At any rate, it suffices to show that this is a problem which society must face soon, honestly and adequately, if our civilisation is not to go the way—the terribly significant way—of all its predecessors.

A Book that Classifies for Study a Thousand Human Traits

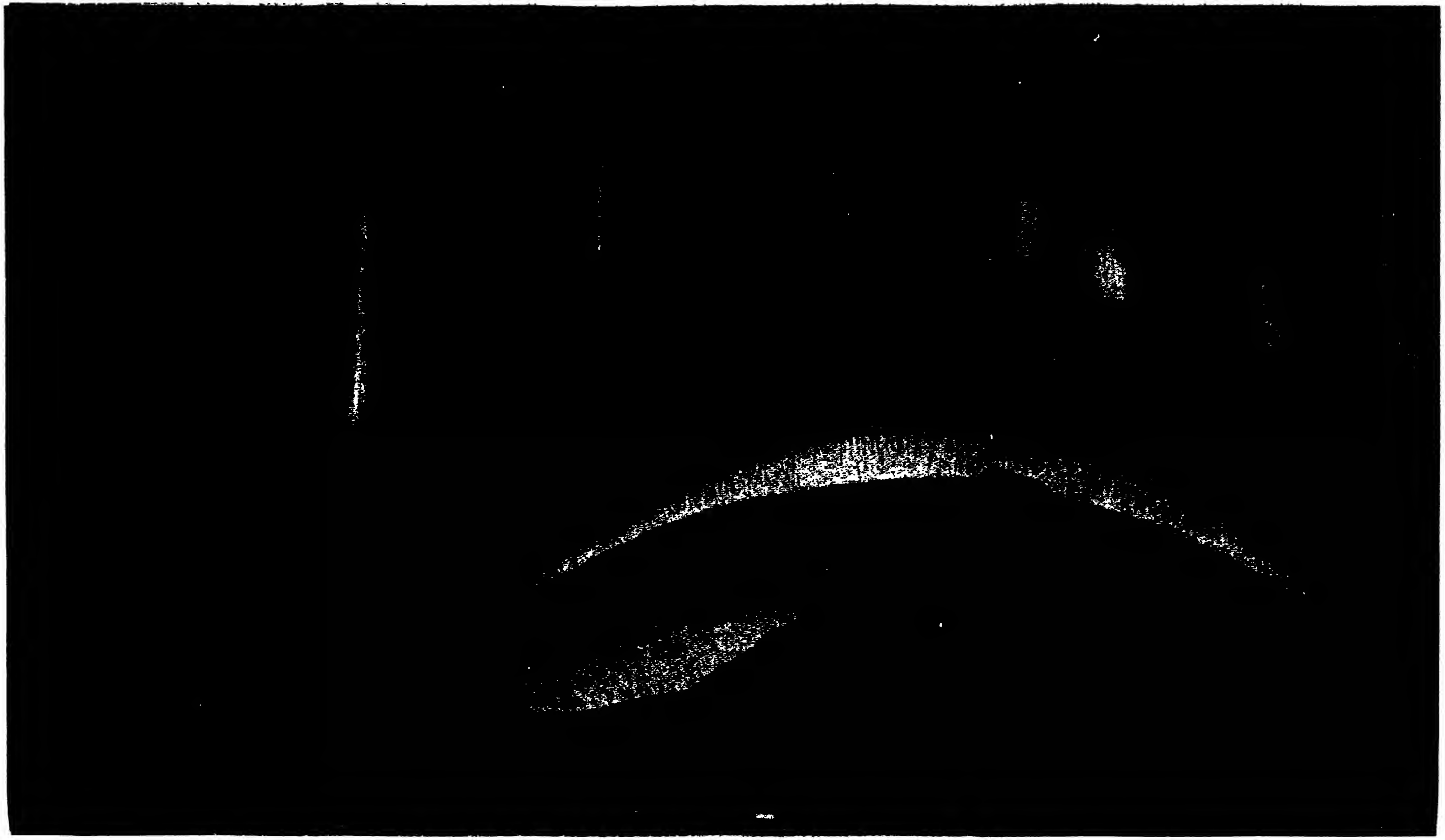
A few words will suffice for the sixth and latest bulletin issued by the American Eugenists. It is called "The Trait Book," and its author is Dr. Davenport. It is the first thing of its kind, and will require early attention in this country, where we have long wasted time for lack of a standard list of human characters, physical, mental, and moral, reduced as far as possible to unit characters, which alone will satisfy the demands of modern genetics. This book includes some thousands of traits, normal and abnormal, carefully classified and indexed. Alas for the writer on positive eugenics, who has to face the problems set before him in the next few chapters of this section, when the necessary knowledge is so far from being obtained that the elementary basis upon which it must be sought has only just been published! But at least due attention can be directed to this valuable instrument for future research, the purpose of which cannot be better described than in the following words, employed in his introduction to it by its distinguished author.

The Need for a Rough Analysis of Qualities into Simple Traits

"In the study of human heredity it has first of all to be recognised that progress will be made only as traits are studied one at a time. The modern science of heredity, indeed, seeks as the element of study the 'unit character.' What are unit characters can, however, be told only by breeding experiments in which the true units reveal themselves as relatively, if not absolutely, constant, unalterable, indivisible things. On the other hand, many apparently simple traits are shown by 'hybridisation,' or the mating of unlike parents, to be complexes of unit characters. The first step in the resolution of human traits is, then, a primary rough analysis into fairly simple traits; and, secondly, the study of the behaviour of these traits in heredity. It is the purpose of this list to afford a list based on such a rough analysis."

So much for the bulletins issued by the American Eugenists, and what they teach.

SOME OF THE GORGEOUS ELECTRICAL PHENOMENA OF THE MYSTERIOUS SOUTHERN SEAS



OUR FOOTHOLD IN SPACE

The Planet We Know—Its Shape, Size, Density, Motion, Interior—How Is It Cooling, and Why?

THE WONDER OF THE AURORA BOREALIS

THE globe whereon we live is the third planet from the sun, from which it is distant about 93,000,000 miles. It is very nearly a smooth, round ball, but is slightly flattened at the Poles, so that its diameter from Pole to Pole is rather less than the diameter through the equator. This difference is so small, however, that if the earth be represented by a globe twenty-four feet in diameter, the equatorial diameter would exceed the Polar diameter by only about one inch. On the same scale, the highest mountains would be represented by elevations of not more than one-fifth of an inch. The globe is therefore very round and smooth.

The spherical shape of the earth is known in several ways. Thus in an eclipse of the moon the shadow cast by the earth on the moon's disc is always circular in outline. Circumnavigation of the globe affords another proof of the same fact. The roundness of the earth is even visible to the eye, when ships are seen descending over the horizon, and the hull is hidden while the masts are still clear, projecting over the sky-line. The degree of curvature may be measured by experiment. Thus if three pillars be erected in a straight line upon a plain, at distances of a mile apart, and the summits of the first and third be exactly levelled with the summit of the middle one, it is found that a line from the summit of the first to that of the third passes about eight inches below the top of the middle pillar. That is to say, the summits of the three columns are on a curve; and from the degree of its curvature the diameter of the earth may be calculated. By measurement of the number of miles in one degree of the meridian it is known that the diameter of the earth is about 7918 miles.

The flattening at the Poles, caused by the bulging out of the equatorial parts due to the rotation of the earth, may be estimated by comparing the length of two arcs of the meridian—one near the equator and the other near the Pole. It is found that a degree of latitude near the Pole is considerably longer than a degree of latitude near the equator, showing that in regions near the Pole there is less curvature in the north and south direction than there is in the equatorial regions. For the purpose of discovering as near as possible the shape of the earth, arcs of meridians have been measured in several parts of the world.

Another method of demonstrating the regular diminution of curvature from the equator to the Poles is by estimating the force of gravity at different latitudes. In consequence of the northern and southern flattening of the globe, the surface of the earth in high latitudes is somewhat nearer to the centre of gravity than it is in the tropics. Any object, therefore, weighed in the neighbourhood of the Poles is heavier than the same object weighed at the equator; and for the same reason a pendulum will vibrate more quickly in high latitudes than the same pendulum will vibrate when near the equator. The difference between the force of gravity at the Poles and at the equator is found to be such that an object weighing 190 lb. at the equator will weigh 191 lb. at the Pole. The experiment has been made with great exactness by means of a pendulum, and the results obtained are corrected for the effects of centrifugal force at the equator. Obviously, the centrifugal force of the earth's spinning increases greatly from high to low latitudes, and makes any object at the equator lighter than it would otherwise be.

The rotation of the earth on its own axis, by which any point on the equator is whirled round at the rate of nearly a thousand miles a hour, is shown in various ways. In the

first place, as Copernicus reasoned, it is very much simpler to suppose that this globe itself rotates than to imagine that the immense host of celestial bodies are revolving round a stationary earth. Again, the telescope shows us that the sun, Mars, Jupiter, and other planets rotate, and it is only reasonable to believe that the earth also rotates. But experiments have proved the fact of this rotation beyond all doubt.

The Positive Proofs of the Rotation of the Earth

For example, if a weight be dropped from a high tower, or down the shaft of a mine, its descent is not exactly vertical, but deviates somewhat towards the east. The reason is that the higher point, from which the falling object starts, being further from the earth's centre than the lower point, at which the object comes to rest, the former is moving eastward, with the earth's rotation, more rapidly than the latter. The falling weight retains, during its fall, the eastward speed with which it started, and thus outstrips the point which was vertically below it, in the direction of the rotation of the earth. Foucault's celebrated experiment shows the earth's rotation in a very striking way. A huge pendulum, consisting of a heavy metal ball supported by a long wire, was hung within the dome of a high building, so that the ball swung quite near the floor, and a pointed rod attached to its lower surface just touched a circular ridge of sand at each swing. The pendulum having been set going in an absolutely true swing, made little marks on opposite sides of the ring of sand. But at each swing of the pendulum the new mark was made at a place slightly removed from the last, and so the plane in which the pendulum swung was found to be moving very slowly round in the direction of the hands of a clock. The fact was that the pendulum retained its original plane of movement, but the floor, with its ring of sand, was slowly rotating with the rotation of the earth.

How the Density of the Earth's Mass is Determined

If suspended at the North Pole, a pendulum of this kind would appear to make one complete rotation of its plane of movement in twenty-four hours, and the rotation would be clockwise. At the South Pole the rotation would take the same period of time, but its direction would be counterclockwise. At the equator there would be no such rotation. At Paris, where the experiment was first performed, the rotation was clockwise because in the northern hemisphere, and the pendulum moved round the circle at the rate of one complete rotation in thirty-two hours. An experiment which is essentially identical with the above has been made with the gyrostat, with the same results.

The density of the earth is rather more than five times the density of water. That is to say, the mass, or gravitative force, of the earth exceeds in that proportion the mass of a sphere of water of the same dimensions. The determination of the earth's mass is a difficult matter, which has been attempted by several ingenious experiments. By estimating as nearly as possible the mass of a mountain, and measuring its attraction for a ball of lead of known weight suspended on a plumb-line, the mass of the earth, whose attraction for the leaden ball is known from the weight of the latter, may be calculated. Or, having estimated the mass of the mountain, it is possible to measure the force of gravity at the mountain top and on the plain below, and to make the required calculation from the difference between the force of gravity in these two situations. Or the gravitative force of a heavy metal sphere upon a smaller ball may be measured, and compared with the gravitative force of the earth upon the same object.

The Elliptical Shape of the Earth's Orbit, and Some of Its Effects

The orbit of the earth is an ellipse, lying in the plane of the ecliptic. The plane of the orbit passes through the sun, which is situated not in the centre of the ellipse but at one of its foci. An ellipse is a curve consisting of points which are such that the sum of the distances of each point from two fixed points is always the same. Thus, if two pins are stuck in a board, and a ring of string is laid on the board enclosing both pins, and a pencil is made to travel round, stretching the string as far outward as it will go, the pencil will draw an ellipse, of which each pin will represent a focus. Plainly, a circle is a special case of an ellipse, in which the two foci coincide. Inasmuch as the sun is not in the centre of the ellipse of the earth's orbit, it is, during part of the year, nearer to the earth than it is at another time of year. The point of the orbit at which the earth is nearest to the sun is called perihelion, and the point at which it is furthest is called aphelion. At perihelion the apparent diameter of the sun is, of course, larger than it is at aphelion; but as the eccentricity of the orbit is very small,

this difference in apparent diameter is so slight as not to be observed except by measurement.

Very little can be said with certainty with regard to the interior of the earth. We know that its heat must be very great, from the rapidity with which the temperature rises as we descend into mines. The density also is great, because the average density of the materials of the crust is considerably less than the density of the earth taken as a whole.

The Argument in Favour of the Solidity of the Earth

But authorities are not all agreed as to whether the interior is for the most part in the solid or fluid condition. The heat is far more than sufficient to melt the most obdurate rocks, but the pressure also is enormous, and may be sufficient to prevent the molten condition. From the resistance which the solid earth, as distinguished from the oceans, opposes to the tide-raising power of moon and sun, Lord Kelvin concluded that the earth is solid to the centre, and has a rigidity greater than that of steel.

There was a period at which our earth was a mass of fiery gases, such as the sun is now. At this stage there was, of course, a continuous loss of heat, due to the radiation of heat into space; but this loss would be more than counterbalanced by a continuous gain of heat, due to the contraction of the planet's mass upon itself, and to the falling in of further meteorites. After a time, however, the balance of gain and loss would turn the other way; for the loss of heat by radiation was constant, but the gain of heat gradually restricted as the condensation and solidification of the earth diminished the possibilities of further contraction. From this time onward our planet was subject to a continuous process of cooling, which is going on at the present day, and will, so far as we are able to tell, proceed until the earth is a dead world like the moon.

The Two Stages of Planetary Life Required by Astronomy

Astronomy seems to require the existence of two definite stages in a planet's history —the accumulation of heat through the clash of meteorites, and then the slow continuous expenditure of heat, with, in our case (and why not in the case of other planets also ?), the evolution of life.

This second period of the earth's life-history, during which it loses heat continuously, is divided by Professor Lowell into two parts, which he names respectively the "self-sustained stage" and the "sun-sustained stage." The huge outer planets Jupiter and Saturn, with their permanent envelopes of cloud, are in the former and younger stage; our own planet, with often cloudless skies and its surface heated by the sun, is in the latter or older stage. The self-sustained stage comes to an end and gives place to the sun-sustained stage as soon as a planet's mantle of cloud is broken through; that is to say, as soon as cooling has proceeded so far that the planet's own surface heat is no longer sufficient to vapourise water.

There is, of course, no doubt that at one time the earth's surface was at a temperature far exceeding that of boiling water, and that consequently there were neither oceans, lakes, nor rivers, but the world's whole store of water was suspended in the atmosphere, at first in the form of uncombined oxygen and hydrogen, then in the form of water-vapour, and finally, when the atmosphere was cool enough, in the form of clouds. This absence of water from the earth's surface is corroborated by the fact that in none of the earlier geological formations is there found any trace of the work of water.

The Condition of the Earth when It Was Cooling Rapidly

In the course of ages the surface of the earth's crust cooled to a temperature somewhat less than that of boiling water; and as soon as it did so the depressions in the surface must have begun to fill with nearly boiling oceans, throwing up enormous volumes of vapour, which was condensed into a murky envelope of cloud over the whole surface of the globe. The earth continued to cool, but through the lapse of vast periods it still remained shut off from the sun by its cloud mantle. The heat at its surface was heat from its own interior, and not heat from the sun. There were therefore no differences of seasons throughout the year, nor any differences of climate from Pole to equator. Everywhere and always there was the same moist, gloomy heat. The whole world was like a dim hothouse, in which there flourished a stupendous vegetation of gigantic tree-ferns and other plants which love heat and damp and shade—the primal forests from which our coal measures were formed.

With further loss of heat, our planet passed at length from this self-sustained stage to the sun-sustained stage. As soon as those steamy seas had so far cooled as

no longer to keep up the dense, universal mantle of cloud, the earth became subject to two influences unknown to it before—the radiant heat of the sun and the nocturnal chill of outer space. Heat from without was able to enter, but inner heat was also enabled to escape. Gradually, as the earth's seclusion was by degrees broken down, the seasons of the year were marked out from one another, and the various climates were differentiated in zones about the globe. The trees began to show the passage of the years by annual rings of growth in their wood, for hitherto they had grown continuously without recognition of seasons. Later, with increasing difference in the seasons, they began to shed their leaves in autumn and to remain leafless until the spring.

Reasons for Supposing that the Earth is Losing Its Water

The earth's escape from the self-sustained stage into the sun-sustained stage was marked also by the first appearance of land animals, in addition to the marine fauna which had existed before.

To judge by what we know of the moon and of the planet Mars, the future history of our planet will be a gradual process of desiccation. The earth's store of water is passing away into space in the form of vapour; and Professor Lowell associates the remarkable extension of desert areas within historic times with this diminution in the total supply of water. The northern parts of Africa were formerly well populated, but are now desert; the ruins amid the arid regions of North America testify that these areas were once fit for habitation; the great inland seas of the world are slowly drying up; and there is reason to believe that the level of the ocean itself is sinking.

Finally, if its fate is to be like that of Mercury and Venus, our earth also will at last cease to spin on its axis, and will turn ever one face to the sun, having one hemisphere parched in eternal day, and the other frigid in endless night.

The Mysterious Natural Phenomenon of the Northern Lights

The aurora borealis, or northern lights, may be suitably dealt with here as a phenomenon predominantly celestial, but visible from time to time on the earth, and in some mysterious way related to the Poles. It is called aurora borealis or aurora australis according as it occurs in the northern or in the southern hemisphere. Auroras are phenomena of exceedingly varied appearance and brightness, and are sometimes of great splendour. They shine out suddenly in the heavens, flashing and darting, and execute the strangest, rapid movements and swift changes in form and intensity. Their origin and constitution are still involved in mystery, and have been the subject of endless speculation. In some parts, chiefly in the Arctic regions, auroras are of frequent occurrence but of inconsiderable extent; others again, though occurring more rarely, are of enormous extent, and are visible over the greater part of both hemispheres.

The recurrence of these displays seems to show some degree of regularity. Various degrees of frequency have been remarked in certain well-defined zones, increasing from the tropics, where no auroras occur, to a region of maximum frequency which constitutes a small, irregular oval, round a point which is known as the auroral Pole, and is situated at about 81° N. 70° W This line of maximum frequency passes by the North Cape, the northern extremity of Novaya Zemlya, the north-eastern extremity of Siberia, Hudson Bay, Labrador, and passes well to the south of Greenland and Iceland. Within this line, towards the North Pole, the frequency again diminishes. Concentric curves of the same oval form mark the diminishing degrees of frequency south of the maximum line.

The Different Forms Assumed by the Aurora Borealis, and Its Local Frequency

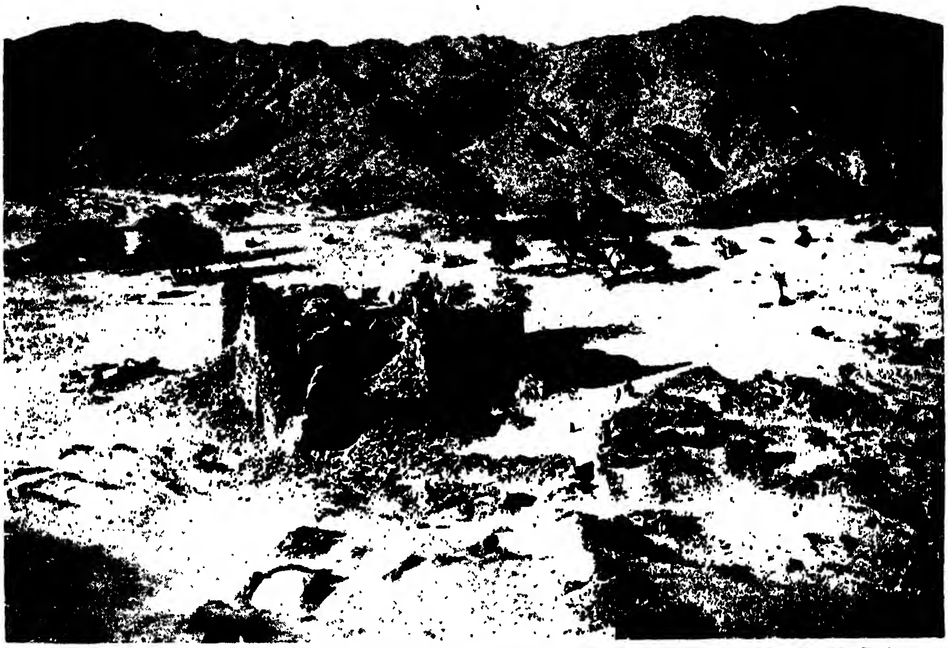
From the shape of the curve it is obvious that auroras are more frequent in America than in the same latitude in Europe. The numbers of auroras recorded give averages of one in ten years for the south of Spain, five a year in the north of France, six a year in London, thirty a year in the north of Ireland, and a hundred a year in the Faroe Islands, along the northern Siberian coast, and in the south of Hudson Bay and Labrador.

The appearance of the aurora varies from that of a mere faintly diffused light to very definite and resplendent forms such as those which are known as crowns or draperies. Again, the faint illumination varies much in extent and brightness, covering sometimes the whole sky, sometimes quite small portions of it, and sometimes glimmering along the edge of the horizon. The light is in these cases usually dimly white, not unlike that of the Milky Way, or may resemble thin, luminous tissues spread out in the sky. Auroras of this type can easily escape observation, as they may be taken for the dying sunset rays or the light of the

coming dawn, or may be nearly obliterated by other illumination, such as moonlight or the glare from cities.

Next we remark a somewhat brighter and more definite form of the aurora, wherein it resembles the clouds known as cirrus—that is to say, the delicate, fibrous, feathery clouds. Indeed, the two phenomena are sometimes indistinguishable, and sometimes occur together or replace one another. Like the aurora, cirrus clouds are often arranged in more or less circular belts, with an apparent convergence towards a definite point in the horizon. Patches of auroral light, less delicate in form than the feathery circular, but sometimes elliptical. They may be homogeneous curves of light, or curves consisting of rays perpendicular, or nearly so, to the direction of the arc. The rays which make up the arc are usually bright and well defined along their lower edge, but fainter at their upper extremity, often fading imperceptibly into the sky. Two or more arcs, usually concentric, are not uncommon, especially when the arcs consist of rays; and sometimes four or five, and even as many as nine, arcs have been seen at one time.

The light often seems to pulsate along these arcs, passing from ray to ray with great



THE ADVANCE OF THE DESERT—THE SAND-SWEPT RUINS OF AN EGYPTIAN FORTRESS

This old fortress, Dareheib Castle, was the treasury as well as a barracks, situated in a fertile plain, to guard the mines of the Egyptian Government hundreds of years ago.

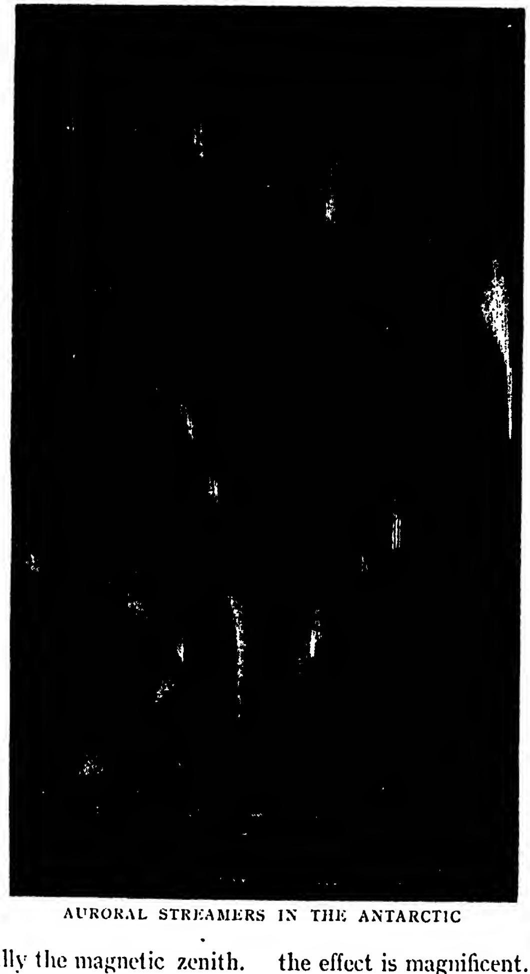
cloud-like lights, also occur; and these are sometimes subject to strange fluctuations, the light shining brilliantly for a moment while contracting in area, and then resuming its more diffuse and less brilliant appearance, very much as if a searchlight were being thrown across the sky.

But the most striking auroras take much more definite and brilliant forms than these. The grander auroras are again exceedingly varied, but the more usual forms are arcs or rays of light, and the magnificent appearances known as crowns and draperies. Auroral arcs are generally more or less swiftness, and producing the effect of an undulatory or fluttering movement in the arc. These rayed arcs are subject to many rapid movements and changes; they move upwards and downwards, vanish and reappear in part or in whole, lose their rayed structure, and for a time become homogeneous bands, and even perform more complex movements than these; thus, the feet of the arc may move in opposite directions, while the vertex remains stationary, as if the entire arc were moving round a vertical axis.

The rays which form the arcs are usually

short, but occasionally reach a great length, stretching upward toward the zenith. Similar rays may exist alone or in groups forming columns, which are subject to equally rapid and varied movements. These rays are often of considerable brilliancy, sometimes sufficient to produce reflections in water or snow. They may be seen to shoot upwards, lengthening themselves rapidly, or to move swiftly in the horizontal direction; sometimes they become fused together to form a fragment of an arc: sometimes there are many separate rays, all converging towards a single point. Some of the quick movements of these rays are peculiarly characteristic of the aurora, and have been noticed from the earliest times; thus the ray, remaining in itself of the same size, may leap with an up-and-down movement, an appearance known in Canada as marionettes and in the Shetland Isles as merry dancers. Doubtless the aurora borealis gave rise to all ancient stories of armies fighting in the skies.

The display known as the crown, or glory, is produced when the rays, packed closely together, converge upon a single point, generally the magnetic zenith. The effect is often one of great magnificence; the rays may form a complete circle and sweep downwards to near the horizon, producing the dome-like effect called by old writers a tent' or pavilion Sometimes the top or centre of the dome is wanting, and the auroral rays then form an immense luminous band around the horizon; and sometimes one side is wanting, and the rays are then said to form a wreath. This crown type of aurora is generally confined to high latitudes, but a few have been recorded in Britain.



AURORAL STREAMERS IN THE ANTARCTIC

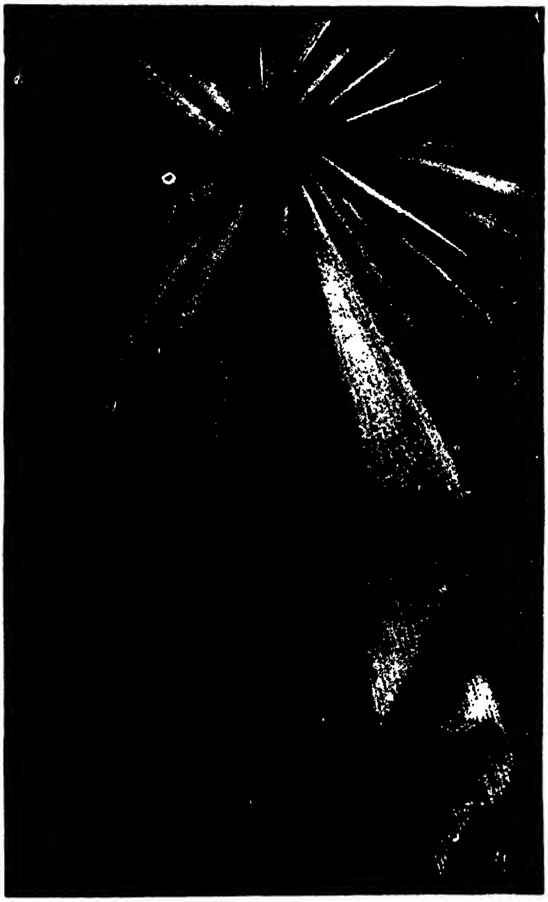
Quite the most resplendent auroras are those known as draperies, the rays being in this case strongly developed and very close together. They are not grouped round a common centre, but join together in less regular form, presenting the appearance of wide bands of drapery, undulating, or as if folded many times upon itself, like a streamer of some light fabric fluttering in the wind. Auroras of this kind, like all others, are usually much brighter and better defined along their lower edge, the light becoming fainter above and merging indistinguishably into the sky. The colours are often superb.

The usual colour of auroras is a yellowish-white, or a silvery white when the light is faint. In the draped auroras there is often a brilliant rose carmine towards the lower edge, sometimes, but rarely, tinged with violet. The greater part is still of yellowish-white, but sometimes above this there is a green tinge, not usually so bright, however, as the red below. When the whole is in movement, like a huge flag floating in the wind, the effect is magnificent. The crown aurora also at times takes on these vivid red and green tints, and then forms one of the most glorious manifestations of the aurora.

This grouping of colours—red, yellowish-white, and green—is also found in isolated rays. If they move in a downward direction the colour becomes intensified to great brilliance, but when the rays are moving upward the colours become correspondingly fainter.

The brightness of the auroral light varies considerably over the illuminated area, and frequently from moment to moment. It is difficult to give any accurate estimate of its brilliancy, but it is fairly certain that it is much less than that of moonlight. Observers in the far North have indeed compared the light of the aurora to that of the moon as an electric light to that of a common gas-jet, but brilliant displays of that kind must be very rare.

The spectrum of the auroral light consists of bright lines, showing that the source of light is gaseous. One of these lines is so dominant that it has come to be considered as the characteristic auroral line. It is in the yellow-green region of the spectrum, and is nearly, if not actually, coincident with a prominent line in the spectrum of krypton, an atmospheric element discovered by Sir William Ramsay. Two other lines are also prominent in the auroral spectrum.



AURORAL CORONA, LOOKING TOWARDS THE ZENITH

It is an open question whether or not the aurora is at times accompanied by a peculiar sound. In some countries it is firmly believed that sounds are heard, during auroral displays, not unlike the rustling of silk or of straw. It is almost impossible to obtain conclusive evidence on this point, because it is never quite possible to exclude other causes for the supposed sounds. Moreover, different observers have widely differing susceptibility to sound. It is not at all surprising if an electrical phenomenon, such as the aurora, is accompanied by a crackling or rustling, audible to acute senses in still, frosty air.

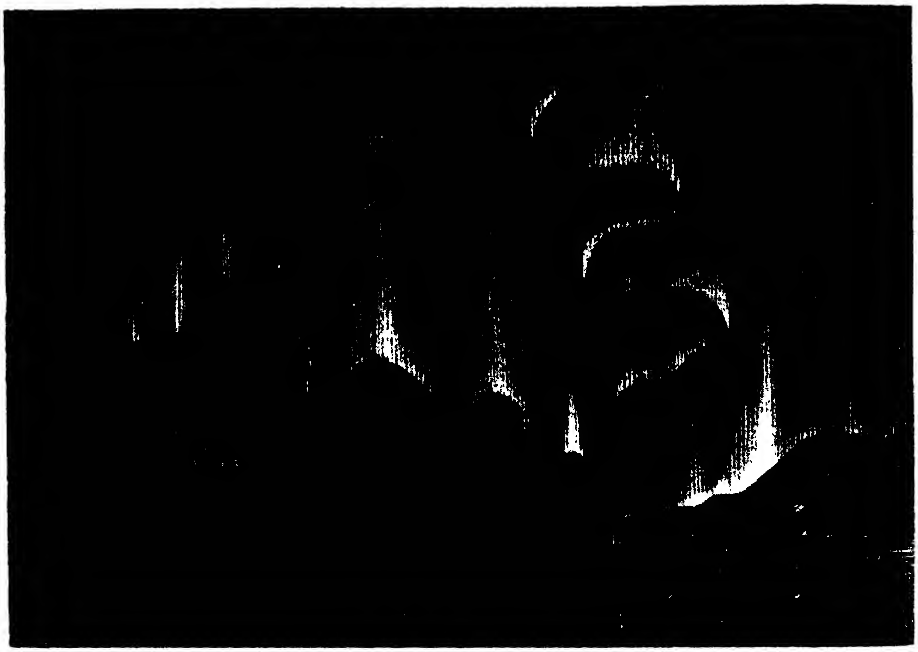
The rapid movements of many auroras, and the merely local character of many more, have made it very difficult to measure the height at which these northern lights are displayed above the earth. For instance, when attempts have been made in Polar regions to measure the angle of a certain point on the aurora from two separate stations, in order to secure a calculation of its height, telephonic communication between the two stations has generally shown that the phenomenon has appeared so differently to the separate observers that they have been unable to fix upon a common point to measure. All the evidence, however, goes to show that the great auroras of wide extent are at a great height above the surface of the earth, reaching probably an average elevation of sixty miles or more; and it is certain that sometimes their height greatly exceeds this figure. An elevation of even three hundred miles has been estimated in some instances.

These high auroras have on several occasions been observed over the whole of Europe, the greater part of Asia, and in Australia, South Africa, and other regions of the South, simultaneously. Indeed, it is probable that at such times the whole earth, with the exception of an equatorial zone about forty degrees in width, is enveloped in the light of aurora borealis and australis. Such, for example, were the great auroras of February 4, 1872, and of September 1, 1859.

Local auroras, on the other hand, are much lower, being sometimes within a hundred yards of sea level, and often low

enough to illumine the under side of clouds, or to be interposed between the observer and distant hills. These low auroras may be of complicated form, such as the draperies and rayed arcs described above. They are visible, as a rule, within only a very limited radius, and are of frequent occurrence in high latitudes. It is believed that this wide difference in height and extent marks a real difference in the character of two distinct phenomena, which are grouped under the common name of auroras; and this belief is strengthened by the fact that the great auroras, high above the earth, and visible in both hemispheres, are always Alaska, 1,30 a.m.; and in Greenland between 4 and 6 a.m.

The cause of the aurora is certainly electric. Thus, during a scientific expedition in high latitudes, a draped aurora of considerable size and travelling rapidly was seen to approach from the south until it passed directly overhead, and swept away towards the northern horizon. In exact correspondence with the movement of the aurora the magnetic needle deviated first to the west, oscillated as the aurora passed overhead, and then deviated to the east. This coincidence was observed many times. These are exactly the movements of the needle which



AURORAL CURTAINS THAT CHANGE THEIR BEAUTY EVERY PASSING MOMENT

accompanied by magnetic disturbances, while the low and local auroras have no relation to magnetic storms. Moreover, a correspondence between the periods of greatest sun-spot activity and those of greatest auroral frequency has been made out.

A daily periodicity in the brilliancy and even in the forms assumed by the aurora has also been noted. For instance, the usual hour at which auroral arcs first appear is 7.50 p.m., the rays at 8.30, and coloured auroras between 10 and 11 p.m., while the palpitating searchlight effects are due about 1.30 a.m. The hour of maximum brilliancy has been fairly well determined for several places; thus, in London, it is 9.15 p.m.; in Canada, 10 p.m.; in Lapland, 10.30 p.m.; in

would have been produced if electric currents directed upwards from the ground had been moving in the place of the aurora. The aurora appears to be essentially a reflection in the upper atmosphere of some disturbance in the magnetic or electrical equilibrium of the earth.

Another phenomenon with which the greater auroras are intimately related is telluric currents. These are currents which arise spontaneously from time to time in telegraph and telephone wires, or any other insulated wires which communicate at both ends with the earth. Auroras are often accompanied by telluric currents of such magnitude as to interrupt the transmission of telegraphic messages.

The small and low auroras show no relation to magnetic disturbances, but appear to be related to certain weather conditions, especially, as we have seen, to cirrus clouds, but also to the existence of ice, and to considerable barometric pressure. The subject is, however, still very obscure.

Theories of the nature and causes of the aurora have been very various, and we need not spend any time over most of them. Scientific opinion is now agreed that some kind of electrical discharge is involved in these displays. Auroras of the higher atmosphere may be closely simulated by the effect of electrical discharges on Geissler's tubes, which contain highly rarefied air; the air within the tubes becomes luminous in immediate response to a sudden change in the electric field surrounding them.

A PHOTOGRAPH OF THE NORTHERN LIGHTS—THE WESTERN END OF A MAGNIFICENT ARC THAT STRETCHED ACROSS THE SKY AT BOSSEKOP LIKE A BLUISH-WHITE MILKY WAY

The aurora is regarded by Edlund as being caused by what is known as unipolar induction, by which electric currents are produced in any sheath-like metallic body which revolves about a magnet at its centre. The earth is a body of this kind, having two Poles to the central magnet, namely the Magnetic Poles, which nearly, but not exactly, correspond with the Poles of its axis. Now, according to the laws of unipolar induction, a molecule charged with positive electricity is subject at the earth's surface to the action of two forces—one driving it upwards directly away from the earth, and the other drawing it towards the nearest Pole. The vertical force is at its maximum at the equator, and diminishes to nothing at the Poles, but the horizontal force drawing the molecules towards the Poles is at its maximum in middle latitudes, becoming nothing both at the equator and at the Poles.

The result is that molecules charged with positive electricity are driven upwards, especially in equatorial regions, so that electricity accumulates in the upper atmosphere. In the tropics this accumulated electricity is discharged principally by means of the frequent and violent thunderstorms which are characteristic of those regions. But as much of the electricity rises to great height in extremely rarefied air, it flows easily towards the nearest Pole, obeying the force which draws it in that direction; and most of it is discharged on the way in the form of auroras.

THE FLEECY CIRRUS CLOUDS THAT FLOAT IN THE THIN UPPER AIR

THE PILED SNOWY CUMULUS CLOUDS THAT ENCUMBER THE HORIZON

PROBLEMS OF CLOUDLAND

The Many Meanings of the Kaleidoscope of the Sky, and what Its Changes do for Man

THE BATTLE BETWEEN EARTH AND SUN

As we have previously stated, the atmosphere always contains a certain amount of water-vapour; and when the amount reaches saturation-point the vapour condenses on cold, solid bodies such as dust or leaves, and forms clouds, mist, fog, rain, and dew. Clouds, mist, fog, rain, dew, are all akin. They are all beads of condensed water-vapour, and the difference between them is chiefly a matter of size and position. When the drops are high in the air and are of such small size that gravity hardly affects them, a cloud is formed. When such small drops are near the ground they make a fog or mist. When drops of various sizes are condensed directly on leaves and stones they are called dew. And when drops are of considerable size, and fall comparatively rapidly through the air, we have rain. But there is no hard and scientific division between these forms and conditions of condensed water-vapour. What seems a cloud on a hilltop when we see it from the plain will seem a mist if we are on the hilltop and enveloped in it; and the distinction between a Scotch mist and an English drizzling rain is certainly a fine one. Still, in a rough way, the several terms indicate several types: and in this chapter we shall separately consider clouds in their typical aspect as condensed water-vapour in the upper atmosphere.

No natural phenomena make a greater appeal to poetry and art than the clouds. They are the mingled banners and meeting oriflammes of the empery of the sun, and of the puissance of the earth. Under their streamers is fought a mighty battle between Heat, and Cold, and Gravitation. Nor in all Nature is there a combat with consequences more momentous. It is a life and death battle. Did the sun win, earth would become a Sahara. Did the sun retire from the unequal contest, all land life would end; there would be no more falling rain, no more rippling rivers, nothing but a brimming sea. Even in the sea life would suffer, for the lime salts would soon be used up, and would no longer be replenished from the land. But the even and recurrent battle means salvation to man, and signifies that all goes well with the world.

Regarded under a less martial metaphor, the clouds represent the lead weights of a wound-up clock; they represent weight lifted by the sun, and the lifted weight represents potential power. But what a clock it is, and what enormous power the clouds contain! They hold all the rivers in the world. Latent in them are the Congo, the Mississippi, the Amazon, Niagara, the Victoria Falls. It is these airy, white, floating clouds that grind down the mountains, that hollow out the valleys, that cut the cañons; it is these white clouds that laid down the mud of the deltas and added Egypt and the Netherlands to the map of the world. Were the water not lifted by the sun, it would be futile and impotent; and equally futile and impotent would it be were it not condensed by the cold and caught back to the bosom of Mother Earth. The height of the clouds is a measure of the work-capacity of the water they hold; and small and dispersed though the drops of water in a cloud may be, yet the aggregate weight of the water-drops must in some cases be enormous.

Regarded yet in another aspect, clouds are the smoke of a furnace—they are fringed with fire. Every drop of water-vapour as it condenses gives forth a quantity of the latent heat which maintained it in a gaseous condition; and the total amount of latent heat given off during the process of condensation of a cloud is very large. Dr. Haughton estimates that the heat supplied to the West Coast of Ireland by

condensation of vapour as clouds and rain is half as much as the sun supplies. The heating value of the Gulf Stream is often emphasised; but it is quite possible that the condensation of the water-vapour borne to our islands by the warm south-west wind is of even more thermal value than the Gulf Stream. The water is of more heating value as water-vapour in the air than as warm waves in the sea.

Regarded cosmically, in its larger relationships with the dynamics of the universe, a cloud floats us into the "dark backward and abyssm of time," and up into the congregation of the stars; for what was the nebula from which the solar system arose but a cloud? And is not the whole world illumined by the carbon clouds of the sun? Clouds are the breath of the universe; and. even as drops of dew, condensing on the cold mirror, betoken that a man is still alive, so do clouds testify that the earth still breathes, and still shares the universal life. The sun is rich in clouds; it boasts about forty different kinds—clouds of carbon, and lime, and iron but the earth now has merely its clouds of water: and when the earth has lost its last water-cloud it will lie dead under a sky as black as crêpe.

The Artistic Inspiration that has had Its Origin in the Glories of Cloudland

Regarded artistically, the clouds are as suggestive and inspiring as the mountains or the sea, and literature is full of fine passages they have inspired. Listen to Ruskin: "And yonder filmy crescent, bent like an archer's bow above the snowy summit, the highest of all the hills—the white arch which never forms but over the supreme crest—how is it stayed there, repelled apparently from the snow—nowhere touching it the clear sky seen between it and the mountain edge, yet never leaving it—poised as a white bird hovers over its nest? Or those war-clouds that gather on the horizon, dragon-crested, tongued with fire, how is their barbed strength bridled? What bits are these they are champing with their vaporous lips, flinging off flakes of black foam? Leagued leviathans of the Sea of Heaven, out of their nostrils goeth smoke, and their eyes are like the eyelids of the morning. The sword of him that layeth at them cannot hold the spear, the dart, nor the habergeon. Where ride the captains of their armies? Where are set the measures of their march? Fierce murmurers answering each other from morning until evening—what rebuke is this which has awed them into peace? What hand has reined them back by the way by which they came?"

In this fine passage, Ruskin commences a discussion of the reason why clouds float; and he comes to the conclusion that we do not know what makes clouds float, but that "It is conceivable that minute spherical globules might be formed of water, in which the enclosed vacuity just balanced the weight of the enclosing water, and that the arched sphere formed by the watery film was strong enough to prevent the pressure of the atmosphere from breaking it in. Such a globule would float like a balloon at the height in the atmosphere where the equipoise between the vacuum it enclosed, and its own excess of weight above that of the air, was exact. It would probably approach its companion globules by reciprocal attraction, and form aggregations which might be visible."

The Place of Clouds that are Always Dropping Taken by Clouds Nearly Formed

Some such theory as this was held by meteorologists for some time, but now the reason *is* known why clouds float, and it is that they do not really float at all, any more than a rainbow floats. The drops of water in a cloud are not balloons, but parachutes; they are always dropping, as their name implies. They fall, it is true, very, very slowly, but still they fall, just as the larger raindrops do. The clouds may be blown by the wind up and down, but individual water-drops cannot escape the law of gravitation, and must fall.

How, then, have clouds such permanency of shape? The shape of a cloud is essentially the shape of the area of condensation, and the general shape is preserved for a time, though the constituent particles are falling, simply because, as condensed drops fall as rain, other small particles are condensed in the area of condensation to take their place.

Dust the Scaffolding upon which the Clouds are Built

This permanency of shape with fluctuation of constituent water drops is well seen in the famous "Tablecloth" that hangs over the edge of Table Mountain. The lower fringed edge of the "Tablecloth" is constantly dripping rain, and yet the "Tablecloth" will keep its shape and size for days, simply because a warm, wet wind is constantly being condensed against the cold mountain.

Every minute droplet in the cloudlet is condensed, and, as a rule, on a grain of dust. This connection between clouds and dust is

so important that though we have already mentioned it, it will be well to note it again here. Dust is the scaffolding of clouds, and without dust they could not be built. Were there no dust in mid-air, the water-vapour could condense only where it touched solid bodies on the actual surface of the earth, and all the rain that comes from the clouds would have to weep itself out on the mountain tops. Accordingly, down the high hills terrific torrents of rain would continually pour, and probably high spires and houses would also condense continual rivers of rain.

Further, the condensation of the water-vapour on the mountain tops would cause a partial vacuum there, and towards all mountain ranges damp winds would go. Indeed, all damp winds would be drawn to the hills, so that the plains would be deprived even of dew. On the plains, accordingly, all vegetation would die, and they would become desolate, barren plateaus traversed by deep cañons. The presence of dust, therefore, in the atmosphere is one of the many wheels within wheels that serve to render the world habitable. Nor is dust ever wanting. There are constant supplies of it torn by the winds from the deserts of the world, belched forth by volcanoes, tossed forth by swaying trees, smoked forth by roaring furnaces. Many miles high the dust must be borne, for clouds are formed ten or more miles high, and twenty million meteorites every day are smashed into dust as they plunge into the atmosphere.

Failing dust, however, it has been shown that atmospheric ions—that is to say, broken molecules of the atmospheric gases charged with electricity—may act as centres of condensation, and thus become the basis of a cloud. If air quite free from dust be saturated with vapour no cloud is formed, but if an electrical current be passed through the air so as to fracture the air-molecules a cloud or mist is at once formed.

Though all clouds rain in a sense, it is not all clouds that condense into drops large enough to produce rain, or that produce enough rain to reach the earth. On the African Karroo, in the dry season, the writer has watched clouds accumulate day after day. Day after day the sky was darkened with them—great, heavy, lowering clouds, which seemed almost to touch the tops of the kopjes—but the great cloud-army crossed the sky and spilt not a drop of rain. And yet the clouds may have contained enough rain to make the whole Karroo blossom like a rose. No wonder, then, seeing the importance of rain, that layman and scientist have both had dreams of finding some way of emptying the great cloud watering-cans upon the thirsty land. The man who succeeds in finding a way to empty a cloud at will will be a benefactor to

THE SOLAR RAYS OR SUNBEAMS SHINING ON THE SEA

The photographs illustrating these pages are by Dr. W. J. Stewart Lockyer

the whole world. Not only will he be able to empty a cloud where the rain is wanted, but he will be able to empty it so that it cannot discharge its contents where it is not wanted. He will be King of the Clouds. So far, all attempts to solve this problem have been in vain.

On the supposition that thunder brings rain, it has often been imagined that rain might be induced by explosions and loud noises, and it is commonly held that the thunder of artillery causes the clouds to pour out rain. But experiment has rather exploded this idea. Indeed, it is based on an unsound theory, for it is not the thunder that produces the rain so much as the rain which produces the thunder. The thunder is due to the increase of electric tension and the leaping through the air of complementary electricities, and the electric tension is increased by the conglomeration of the minute cloud droplets into rain-drops; and any direct effect of thunder and lightning in causing a fall of rain is due not to the noise of the thunder, but to the effect of the electrical discharge of the lightning in producing ions which act as centres of condensation.

The fact that ions can act as centres of condensation has led to attempts to condense clouds and mists by electrical charges. So far, attempts, restricted chiefly to London fogs, have met with some measure of success.

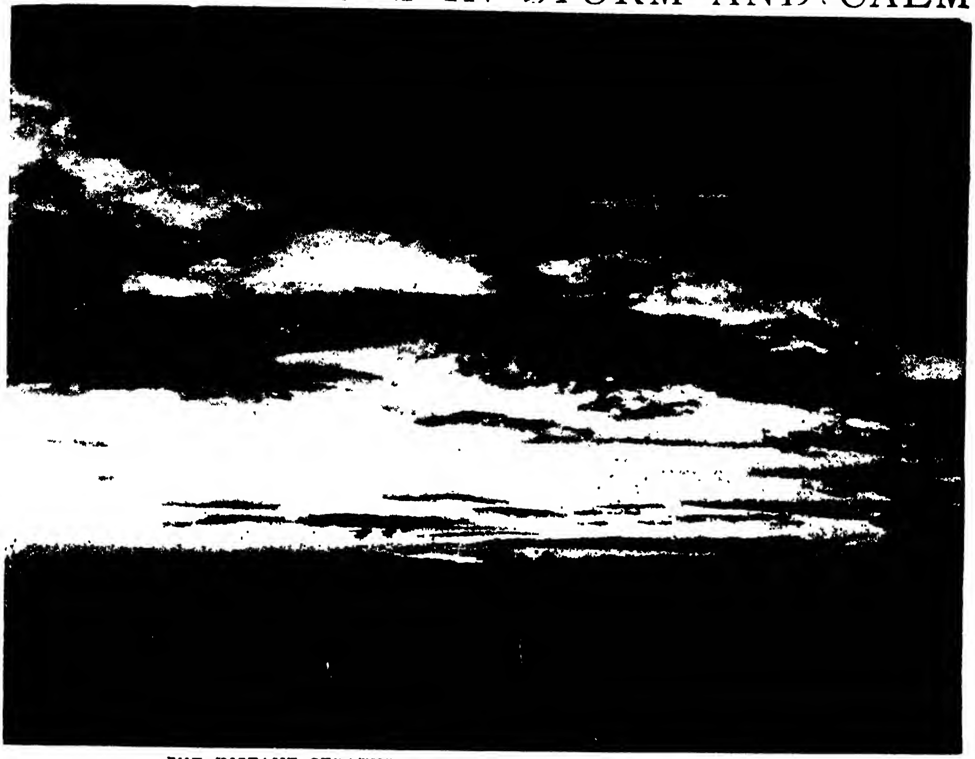
But clouds are more than aggregations of fine dust and fine drops of water: they perform other functions besides watering the earth, for they serve as regulators of heat. On the one hand, they act as wet packs and wet compresses, keeping in the heat of the earth; on the other hand, they act as parasols and tents to keep off the heat of the sun. Its action in the latter respect is well known. We all know the sudden chill that falls upon the earth when a cloud passes in front of the sun. We all know the difference in the heat of the sun when skies are cloudy and when skies are clear. But the action of the clouds in conserving the heat radiated from the earth is not so well known. And yet it is of great interest and great importance.

When the sun heats the earth, the earth, like all hot bodies, radiates away its heat again, and if the atmosphere be clear the heat leaks away rapidly and irretrievably. But if we put the glass of a hothouse between the earth and the sky, the heat radiated from the soil is radiated back again from the glass, and so the heat is economised and conserved. Just like the action of the glass of a hothouse is the action of the clouds. Supposing the early part of the day has been sunny and bright, and the earth and sea well warmed by the sun-rays, then a cloudy sky in the evening will act as a blanket and keep the earth warm all night by radiating back the heat that would otherwise leak away. If there be no clouds, the heat will radiate away fast, and thus it happens that clear, starry nights are often frosty, and that dry climates have more violent changes of temperature than wet ones. On the island of Teneriffe, where the sun shines all morning, and where a cap of cloud is condensed on the Peak almost every afternoon, the heat acquired by day is conserved by night, and the difference between night and day temperatures is very small.

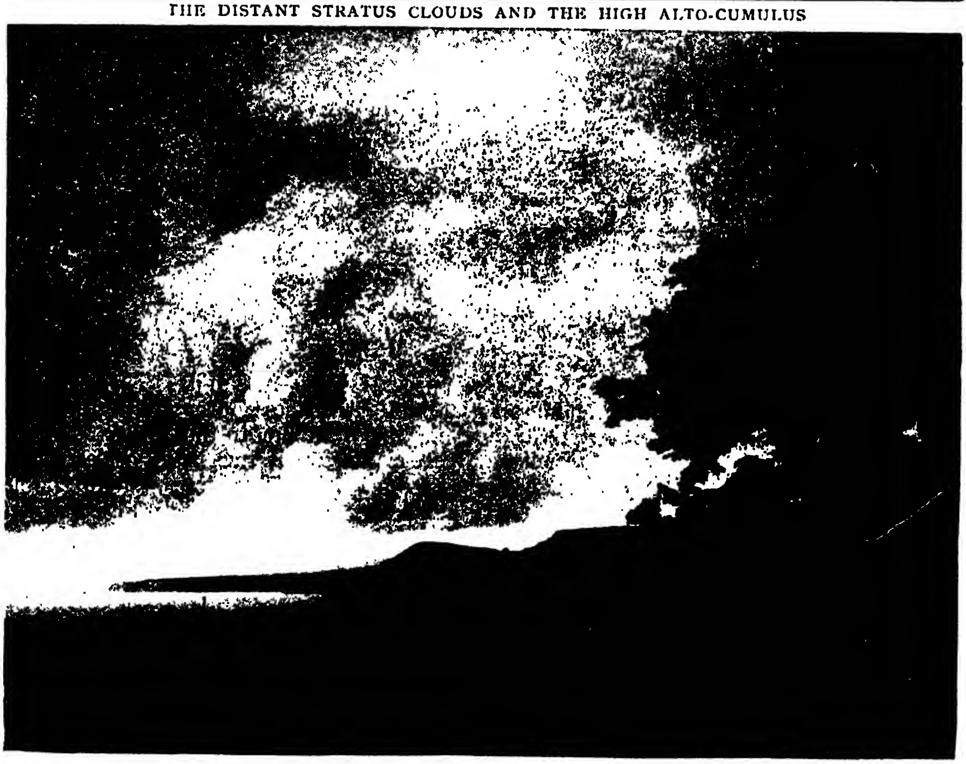
CIRRO-CUMULUS, OR MACKEREL SKY

The colours and shapes of clouds are very striking. In an eloquent passage Reclus declares: "Among all the images, whether fearful or graceful, that the fancy of man can dream of, there is not one which is not to be found in the vapours of space. By their fugitive outlines clouds resemble flights of birds, eagles with outstretched wings, groups of animals, reclining giants and monsters like those of fable. Other clouds are chains of mountains with snowy summits; others, again, represent immense cities with gilded cupolas. Poets see in these groups distant archipelagoes, where the happiness so much sought for, and which does not exist on this earth, is to be found.

CLOUD-EFFECTS IN STORM AND CALM



THE DISTANT STRATUS CLOUDS AND THE HIGH ALTO-CUMULUS



THUNDER-CLOUD—A BLEND OF CUMULUS AND NIMBUS

Superstitious people, often pursued by the terror of their own crimes, see in them bundles of weapons, war-horses, armies in battle array, and massacres. The light playing in this fantastic world of images increases still more their astonishing variety; all imaginable shades shine over these floating bodies, from snowy whiteness to fiery red; the sun colours them successively with all the graduated tints of dawn, daylight, and sunset; meadows and forests are reflected there in greenish tones, and the sea itself is produced vaguely by a colour of metallic brilliancy recalling that of copper or steel."

The colouring of clouds has become to us rather a commonplace—so much a commonplace that we accept it with more admiration than wonder. "But what," asks Ruskin, "should we have thought if we had lived in a country where there were no clouds, but only low mist or fog—of any stranger who had told us that, in his country, these mists rose into the air and became purple, crimson, scarlet, and gold?"


A SOLAR HALO

How does it come that clouds are coloured? They are coloured mainly by the dust. If there were no dust, and if clouds were all condensed upon ions, all clouds would be white. The colour, like the blue colour of the sky, is due to the scattering of certain rays of light as they break on the dust particles. So infinitesimal are the rays of light that dust is to them as rocks are to the billows of the sea. It is chiefly at sunset that the most gorgeous colours appear, because at sunset the rays of light slant through the lower atmosphere, which is charged with the larger particles of dust; and so the greater waves, the red and orange, are broken, and stain the sunset clouds. For a year after the great eruption of Krakatoa, in 1883, there was a series of magnificent red sunsets, due, no doubt, to the enormous quantity of dust ejected by the volcano.

Though the shape of clouds is so various, meteorologists have attempted to classify the shapes. The original classification, made by Luke Howard in 1802, distinguished the following shapes: Cirrus, Cirro-cumulus, Cirro-stratus, Cumulus, Cumulo-stratus, Stratus, and Nimbus. More recently, however, the International Meteorological Committee have divided the clouds into no less than ten classes: 1. Cirrus; 2. Cirro-Stratus; 3. Cirro-Cumulus; 4. Alto Stratus; 5. Alto-Cumulus (great waves); 6. Strato-Cumulus; 7. Nimbus (rain-clouds); 8. Cumulus (wool-pack clouds); 9. Cumulo-Nimbus (thunder-cloud or shower-cloud); 10. Stratus.

The three chief types of clouds are the Cirrus, Stratus, and Cumulus.

The cirrus clouds, as the name—*cirrus*, a curl—itself indicates, are white, curly clouds like curly hair or curly feathers. By sailors they are known as *cats' tails* and *mares' tails*. There may be thousands or tens of thousands of these curly wisps in the field of sight at one time, and they are often arranged in belts of parallel rows. "Flocks of Admetus under Apollo's keeping," Ruskin calls them: "who else could shepherd such? He by day, dog Sirius by night, or huntress Diana herself, her bright arrows driving away the clouds of prey that would ravage her fair flocks."

Cirrus clouds always float five or ten miles high, so high that they often drift in quite contrary directions to the lower cloud, so high that their vapour is frozen into minute crystals of ice. The faint haloes which sometimes appear round the sun and the moon are due to these crystals. When the crystals melt, the cirrus floats lower, and becomes a cirro-cumulus, small globular masses arranged in groups or lines producing the appearance known as mackerel scales. The cirrus may become a cirro-stratus, and spread as a thin film or tangled web over the sky. This form of cloud also consists of crystals, and forms haloes round the sun and moon. The cirrus usually presages wind, with rain or snow.

The cumulus clouds, or wool-pack clouds, the "cloud-chariots" of Ruskin, are the most majestic and impressive of all clouds.

They look like colossal fleeces piled up into a dome on a horizontal base; and often, when piled up on the horizon, they look like a range of snowy mountains with rounded summits. The cumulus moves in a solemn and stately manner, and, since it represents a very heavy load of moisture, it does not float at the same altitude as the cirrus, and rarely is more than two miles high. When cumulus clouds are closely packed into rolls and cover the whole sky they become strato-cumulus. The cumulus cloud is formed by the condensation of currents ascending from the heated, warm, moist air, and it is therefore a day cloud, and especially an afternoon cloud. When of moderate size, and melting away towards evening, they usually indicate a spell of good weather; but if they are of huge size, and do not melt away in the evening, they signify rain.

A RAIN SQUALL—NIMBUS CLOUD WITH CUMULUS IN THE DISTANCE

The stratus cloud is a uniform layer, or sheet, of cloud floating a little distance above the ground. It is essentially a night cloud. It is usually formed towards night, when the cooling of the earth's surface condenses vapours that in the heat of the day have been floating at greater heights. When it occurs in the morning it is often dissipated during the day, and it is indicative of a continuance of good weather. When it is broken up into irregular shreds it is known as fracto-stratus.

Still a fourth cloud, the nimbus, or rain-cloud, must be described. The nimbus is a dark, thick, shapeless cloud with ragged edges, from which rain or snow usually falls. It floats about a mile high, and from its top surface it throws off cirri, known to sailors as scud, and more or less numerous in proportion to the severity of the rain-storm. A modification of the nimbus is the so-called cumulo-nimbus, thunder-cloud, or shower-cloud. Its base is a dark, thick, shapeless cloud like the nimbus, but it is topped by heavy masses of cloud rising in the form of mountains turrets, or anvils, generally surmounted by a sheet or screen of fibrous appearance (false cirrus). Sometimes, especially in the case of spring showers, cirrus clouds are also given off from the edges of the cumulo-nimbus.

The proportion of sky covered with cloud is generally registered by meteorologists according to a scale in which 0 represents a cloudless sky, 5 a sky half clear and half clouded, and 10 a sky which is covered with cloud or overcast.

Under the category of clouds, we may consider dew. A dewdrop is just a lowly cloud-drop. As moisture gathers on the dust floating over the Matterhorn, so also does it gather on the daisies in the morning meadows. One drop is wedded to dust, another drop wedded to a daisy, but the marriage laws are the same in both cases.

For centuries dew was a mystery and a miracle. It was noticed to be most plentiful on clear, calm, starry nights; and hence the ancients conceived the beautiful idea that the dew came from the stars, and when it was noticed that there was most dew on cold nights, the cold, too, was supposed to come from the stars.

But closer observation upset this theory, for it was found that dew sometimes forms on the under surface of leaves and stones, and that the formation of dew depends very much on the nature of the object bedewed. And so it became understood that dew is simply moisture condensed on cold bodies, much as the human breath condenses on a cold mirror. The reason why clear, calm, cloudless, starry nights are dewy nights is simply that on such nights the heat from the surface of the earth radiates away more freely, and the cooled objects therefore become more efficient condensers. On cloudy nights, on the other hand, the clouds act as a blanket, and keep the surface of the earth warm, and the warmer surface fails to condense moisture and to form dew.

PRESERVING THE BALANCE OF NATURE

The left-hand picture is the egg of the hover-fly, magnified ; the centre is its newly hatched grub, and on the right is a young grub raising itself on its tail-end on a sweet-pea leaf and seizing its first green-fly.

These four pictures show the stages by which the full-grown grub of the hover-fly seizes a green-fly, and extends its body to feed on the softer parts of its victim, rejecting the empty skin and legs, the whole operation occupying less than a minute.

The pupa, or chrysalis, into which the grub is transformed, and two views of the perfect insect resting just after it has emerged

THE LIFE-HISTORY OF THE HOVER-FLY, AND ITS WARFARE UPON THE GREEN-FLY

Photographs by Mr. J. J. Ward

THE BALANCE OF NATURE

Illustrations from Darwin of the Struggles for Existence Going On Between Different Types of Life

DARWIN SUPPORTED BY LATER SCIENCE

In Chapters 8 to 14 of this section we discussed the doctrine of organic evolution, not least with reference to the work of Darwin; and, having found that a new science of heredity is required before we can attempt to answer the question *how* organic evolution has come about, we discussed, in Chapters 15 to 22, our existing knowledge of what is now called genetics. Not yet, as we have seen, can positive science explain the origin of those "originating variations," as Professor Bateson calls them, upon which the origin of species depends; and that is the humbler verdict of our own time upon the problem which many asserted Darwin to have solved once and for all in 1859.

But this is very far from meaning that the life-work of that master-seeker was fruitless or unavailing. On the contrary, having done our best to deal with the more universal and philosophical aspects of the problem of evolution, and having seen that we must confess our ignorance while we search for more minute and exact facts of genetics, we must now return to another aspect of the science of life. Almost ignoring the problems of origin and destiny, we must again survey the world of life as we find it at any given time, such as our own, and we must look afresh at certain great facts, of the utmost practical importance, for which the long preceding discussion of theory was no bad preparation, and in which we have no better guide than Charles Darwin. Never again will men attribute to natural selection the powers of Creative Deity, as Darwinism, logically interpreted, seeks to do; never again will they have to try to solve the problems of evolution without the help of modern genetics; but we are very far from the day when we can do without Darwin's profound and searching observation of the facts of the living world as they are displayed at any given time. We reject his theories and the colossal superstructure of mechanical philosophy built upon them by his followers, but we shall do well to learn humbly from him, as a guide to the world of life as it exists at any moment.

It has advisedly been asserted that this is a matter of practical importance, and we shall in due course discover the full significance of that objective, when we realise that the facts of death and disease, and the problems of maintaining the health and prosperity of mankind, can mostly be resolved into Darwinian terms of the struggle for life, the balance of Nature, and the mutual adjustment and competition of the myriad species of the living world.

Another way of stating this idea is that the modern conception of the greater part of what we call disease, the conception whose practical establishment we owe to Pasteur, is *biological*; it is the conception of disease as a natural fact of the living world, which has a biological explanation and must be biologically understood if it is to be placed within human control.

No doubt Darwin wrote before the modern era in the study of disease, and knew nothing of what Pasteur and his followers were to show; but it remains true that, though Darwinism can no longer be regarded as the key to the supreme problem of organic evolution, yet the Darwinian view of the living world is that alone which gives us the real explanation and understanding of the problem of disease as elucidated by Pasteur and his successors. In a word, they have shown us that consumption, for instance, is due to a living plant, and thus this most deadly of all diseases is none other than an illustration of the Darwinian theory of the struggle for life between one species and another. To Darwin we must therefore

return, for a fresh beginning, if we are finally to place ourselves abreast of modern knowledge in these matters which so closely and personally concern us all. And it is not unbecoming to note that, though the present generation rejects Darwin's conclusions on the main issue, on the other hand it goes back to Darwin for the foundations of the true theory of disease, as that theory is being slowly built up by contemporary students.

This is the inevitable and just result of honest labour in science. Over and over again, as in this case, the theory or theories fail to withstand the test of time; but if the facts on which they were built are themselves well and truly laid, then the labourer has not toiled in vain. In the upshot we shall clearly see that our present attitude towards the problems of disease, and our present methods of solving these problems, methods which are meeting with ever-accelerated success, are based upon those biological ideas, those ideas of living nature as a whole, which Darwin first gave to the world. And our first business now is to remind ourselves of what he saw and said; for there is a great deal more in the "Origin of Species" than that theory of natural selection which we have already discussed.

The Enormous Increase in Numbers of Every Species as Soon as Checks are Removed

In the fifth chapter of this section we saw how rapidly living creatures reproduce themselves and multiply under favourable conditions; and this tendency is so important that Darwin concluded his own study of it with the following words, to which we must attach the weight he recognised in them.

"In looking at Nature, it is most necessary to keep the foregoing considerations always in mind—never to forget that every single organic being may be said to be striving to the utmost to increase in numbers; that each lives by a struggle at some period of its life; that heavy destruction inevitably falls either on the young or old, during each generation or at recurrent intervals. Lighten any check, mitigate the destruction ever so little, and the number of the species will almost instantaneously increase to any amount."

In due course we shall see how these words apply to species of which Darwin had never heard or dreamt, such as the *bacillus tuberculosis*, as well as to *homo sapiens*, and to the mortal struggle between them, which man, now roused at last, intends shortly to win. But all such cases as that involve a particular form of the "struggle for life," and the "balance of Nature," which we call parasitism: and before we deal in detail with parasitism and the most important parasites we must try to get a just and adequate idea of the balance of Nature as a whole.

First, we must observe that our study now concerns itself with just that aspect of the struggle which we put aside as relatively unimportant when we were discussing "natural selection." Natural selection and the struggle for life may and do operate both between different species—as, say, lion *versus* tiger in India, or man *versus* tubercle bacillus anywhere—and between different members of the same species.

The Problem of Disease as a Struggle Between Different Species

Darwin himself carefully insists that the most important part of the struggle from the point of view of natural selection and evolution is that between different members of the same species. This has been recently insisted upon afresh by the most distinguished of living Darwinians, Sir E. Ray Lankester, and we were the more careful to regard it in an earlier chapter, because this is the aspect of "natural selection" which is commonly ignored in popular discussion of the subject.

But now the time has come when, for reasons concerned with the problems of disease, we must carefully recognise the importance of the struggle between one species and another. That struggle may be even less important, from the point of view of the origin of species, than Darwin himself thought it; but we are to learn that it is not only of enormous importance in relation to the problem of the origin of disease, but practically *is* that problem.

The Delicate and Unstable Balance Between Species All the World Over

If we consider the living world at any moment, we see a vast number of species, animal and vegetable, high and low, some very numerous, some very scarce, some spread everywhere, others confined to very limited parts of the earth's surface; and if we go on watching, we observe that, on the whole, these proportions, numbers, and particular distributions of species remain constant. On the whole, there is a balance between them, which we call the balance of Nature. We recognise at once that it is an extremely delicate and unstable balance, sensitively fluctuating from moment to moment, but yet there is a balance on the

whole. Given some constancy of external conditions, no violent alteration of climate, no interference by man, we find that, though all species are striving to multiply, on the average none either increase or decrease in numbers.

There is a balance between them perhaps even more closely analogous than may at first appear to what we call the balance of power in Europe. Each species has a "sphere of influence," a country which it occupies—as if we said Thrush-land, or Oat-land, instead of Angle-land or Scot-land—a "hinterland" which it controls, even remote spots which it occasionally or regularly colonises, as in the case of migrating birds. This is a state of balance like that of Europe, but it is also a state of struggle, none the less real because largely carried on in secret, also like that of Europe. Just as the different varieties of men in Europe, grouped as nations, are perpetually struggling against each other for food—which is what the struggle for life or power ultimately comes to—so the different species of the living world are perpetually struggling against one another; and the first fact which we have to learn is that the balance of Nature, which might be thought peaceful as the condition of Europe, in the absence of ostensible military war, seems peaceful—is really active, passionate, military *à outrance*.

The Difficulty of Realising how Universal and Tremendous is the Struggle for Life

We find it very difficult to realise the facts, because we are misled by what we see, and do not realise what is going on underneath, just as we do not realise how the Chancelleries and the industries of Europe are all the time fighting each other. But if we fail to appreciate the real meaning of the balance of Nature, and fancy that it is the result of agreement, or arbitration, or mutual toleration, or lack of desire for more, on the part of living species—at least we have the excuse that Darwin himself found it difficult to keep in the forefront of his own thought the fact which he so clearly demonstrated. Here are his own weighty and memorable sentences.

"Nothing is easier than to admit in words the truth of the universal struggle for life, or more difficult—at least, I have found it so—than constantly to bear this conclusion in mind. Yet unless it be thoroughly ingrained in the mind, the whole economy of Nature, with every fact on distribution, rarity, abundance, extinction, and variation, will be dimly seen or quite misunderstood. We behold the face of Nature bright with gladness, we often see superabundance of food; we do not see, or we forget, that the birds which are idly singing round us mostly live on insects or seeds, and are thus constantly destroying life; or we forget how largely these songsters, or their eggs, or their nestlings are destroyed by birds and beasts of prey; we do not always bear in mind that, though food may be now superabundant, it is not so at all seasons of each recurring year."

Nature a Sensitive Expression of Infinite and Warring Activities

So wrote Darwin, but we now have this notable advantage over him—that we are able to bring in the modern idea of disease to our aid, and to confirm his views of the real meaning of the "balance of Nature" as the resultant of unceasing struggle, by our appreciation of the unceasing struggle between man and microbe which goes on under the superficially peaceful surface of our lives.

If we follow Darwin's own observations we begin to see what this balance of Nature really depends upon, and how intensely unstable it is—just because of the infinite and warring activities of which it is the sensitive expression. Thus writes Darwin: "On a piece of ground three feet long and two feet wide, dug and cleared, and where there could be no choking from other plants, I marked all the seedlings of our native weeds as they came up, and out of 357 no less than 295 were destroyed, chiefly by slugs and insects. If turf which has long been mown—and the case would be the same with turf closely browsed by quadrupeds—be let to grow, the more vigorous plants gradually kill the less vigorous, though fully grown plants; thus out of twenty species growing on a little plot of mown turf (three feet by four) nine species perished from the other species being allowed to grow up freely."

The Enlarged View of the Struggle for Life Seen by the Microscope

In these famous observations Darwin saw, and we see, how real is the struggle between species; and we can indefinitely supplement what he could see, by means of the modern microscope, which has shown us the soil crammed with tiny forms of life, animal and vegetable, kinds of amœbæ and moulds and bacteria, which are all struggling with each other and with the visible plants; and we begin to learn how the visible result, such as the survival of a certain eleven species and the death and extinction of a

certain nine, out of twenty, very largely depends upon the invisible struggle for life under the surface of the ground, and the balance of species which results there. For we are finding that the success of such and such a species as against another, as of wheat rather than weeds, may be essentially due to the particular " balance of Nature " between the microscopic vegetables that cram the soil—if certain of those preponderate, the weeds will flourish; if others, the wheat will flourish.

Put in another way, this may simply mean that wheat is subject to epidemics and parasites, as man is, and that the survival of wheat, or the death-rate among young seedlings of wheat, may be due to the balance of Nature in the soil which is their food, just as the infant mortality in any given year may be modified by the " balance of Nature " between the various species of microbes that flourish in the food given to babies. This, the reader will see, is simply a revelation. We realise that the " balance of Nature " and the " struggle for existence " are illustrated *everywhere* throughout the living world.

The Conquest of Disease—Getting the Master-Hand Over Life that Would Live on Man

Wheat has its so-called " diseases," just as man has, and struggles against microbes which destroy or poison its food (the soil); is helped on by other microbes, which destroy the dangerous microbes, just as man fights against the microbes which infest *his* food, or is fortuitously helped by other microbes (such as the microbe of sour milk), which keep down the numbers of the dangerous microbes. The death-rate among wheat seedlings or human seedlings, and the consequent balance of Nature between wheat or man and their respective visible competitors, may thus depend upon the result of the struggle for existence between the particular microscopic forms of life found in the soil in the one case, and in milk in the other case. Having grasped this, let us add the further complication that man is growing the wheat to live upon, that man provides opportunity for the wheat and favours its growth and multiplication only in order that, a little later, he may destroy and consume it, which means that man both struggles for and struggles against the species we call wheat; and further, that the result of this particular balance largely determines the multiplication of man and his power of struggling against his special competitors, such as the tubercle bacillus—and we begin to realise what the struggle for existence and the balance of Nature mean, to a degree which was never imagined even by the mind of Darwin himself. And the student will begin also to see what we mean when we speak of the *biological* conception of disease; and to see that only in biological terms like those which Darwin taught us to understand and employ can man hope to achieve the " conquest of disease "—which seems now to mean the master-hand over those other forms of life which try to live upon the food *he* requires, or, more daring still, try to live in his own blood and upon his own tissues.

Darwin's Foreshadowing of the Parasitic View of Disease

But if we proceed with our survey of Darwin's pioneer work in this field we shall see that his splendid thought and observation led him to the very gates of the knowledge which we now possess, for he did not omit the fact of parasitism, nor fail to see that this is an aspect of the struggle between one species and another. Here is the truly remarkable paragraph which seems to have escaped previous commentators, but which serves as an exact introduction to the modern view of disease.

" When a species, owing to highly favourable circumstances, increases inordinately in numbers in a small tract, epidemics—at least, this seems generally to occur with our game animals—ensue; and here we have a limiting check independent of the struggle for life. *But even some of these so-called epidemics appear to be due to parasitic worms, which have from some cause, possibly in part through facility of diffusion amongst the crowded animals, been disproportionately favoured; and here comes in a sort of struggle between the parasite and its prey.*"

Darwin Vindicated by Pasteur's Discovery of Parasitic Microbes

We have italicised the last sentence in order to indicate its interest and importance as foreshadowing views of disease which are now becoming familiar to all of us. Instead of game animals, living too crowded together, let us consider the case of human beings in conditions of overcrowding, and, instead of a parasitic worm, let us think of a parasitic microbe like that of consumption. At once we see that Darwin wrote words which Pasteur and his followers were soon to justify when he said, " Here comes in a sort of struggle between the parasite and its prey." It is that " sort of struggle," which Darwin thus almost apologetically included under his general theory, that now is seen,

by means of the "germ-theory" of disease, to be probably the most important of all the aspects in which Darwin's ideas illuminate and guide us.

But we must be careful to observe that the "balance of Nature" has a double aspect. It does not merely depend upon cases where one species fights against another, but also includes innumerable cases where species serve one another. As we have already seen, and as Darwin expressly noted himself, we have no instance in Nature of one species being adapted *in order to* serve another. Each species for itself is the rule.

The Balance of Nature Dependent upon Mutual Service as well as Competition

But the balance of Nature is, nevertheless, largely dependent upon the fact that species incidentally and accidentally serve one another—as in the case, familiar to everybody, of the birds which eat stone-fruit, thus serving themselves, but thereafter effect a scattering of the stones, so that the seed is spread and sown, and the bird, in serving itself, thus happens to serve the species which it attacks. The balance of Nature comprises innumerable examples of this kind of relation, and indeed largely depends upon them.

We must therefore beware of supposing that though species only live for themselves their interests are therefore inimical to those of all other species. Except for the cases of the essentially debased and vicious thing called parasitism, that is far from true. The balance of Nature largely means that the various species, in serving themselves and living their own lives, serve each other. Man fights against and masters other species: but if all other forms of life were suddenly to disappear, man would follow them after a brief interval of cannibalism.

To the supreme example of this balance of living species we have already made some allusion, and we need scarcely do more than remind ourselves of it here, for it depends upon those facts of the green leaf which the next chapter will discuss. It is, of course, the relation between the vegetable and the animal kingdoms.

The True Relation Between Different Species Generally Reciprocal

Perhaps it is a rather one-sided sort of balance, for indeed the vegetable kingdom could survive if animals were to vanish, while animals are absolutely and wholly dependent upon plants, in virtue of the powers of the chlorophyll of green leaves. Nevertheless, as our illustration of the bird and the fruit-tree serves to show, and as is further shown by the immensely important function of insects in the fertilisation of flowers, there is no doubt that the vegetable world as a whole is greatly the gainer by the co-existence of animals, even though animals as a whole are, in a sense, "parasitic" upon the green plant. Thus the two great divergent lines or stems of the "tree of life," which have been developing along their own lines for so many years, are naturally interdependent, and their evolution and development could not have achieved present results if, at every age and in a myriad ways, plants and animals had not been reacting upon each other. It is fair to the animal world, including ourselves, also to add that, though we are undoubtedly dependent for our "daily bread" upon the vegetable world, this relation can scarcely be called parasitism if, in point of fact, it works out for the advantage of the vegetable world, as it does. The bodies of animals, when they die, are reduced to simpler chemical compounds, and finally serve as food for plants—even the plants of the very kind upon which the living animal fed. Thus the relation is reciprocal; and what we call the balance of Nature may also be described as "the cycle of life," in virtue of the cyclic, circular, or wheel-like way in which the forms of life serve, or take advantage of, each other.

The Lichen as an Illustration of Symbiosis, or Partnership

No better illustration can be found of what is not parasitism, though not unlike it in non-essentials, than the lichen, which is really an alga, or green plant, and a fungus living together. Each species, no doubt, is for itself, but each serves as well as gives, and therefore there is no degeneration. The alga possesses chlorophyll, and can therefore feed itself from the air, while the fungus, which avails itself of the food thus obtained, provides shelter, mechanical support upon the rock or stone, and also water essential for both alga and fungus. This is technically called *symbiosis*, or living together. Symbiosis is not parasitism, but obviously there is a temptation, so to say, for either partner to become "slack," to leave too much to the other, and become parasitic, if the other permits. The whole living world is a symbiosis, as we have already tried to show, and not least of all the magnificent partnership between the animal and the vegetable kingdoms. But if we remember that each species is all the time essentially concerned with itself and its own interests, we shall see how symbiosis always runs the

risk of leading the way to parasitism, with its consequences of failure, disease, and death.

Such considerations will help to prepare us for the study of parasitism, the evolution of parasitism, and thus the genesis, and possible human control, of what we call "disease." Meanwhile let us observe that while symbiosis is a vital principle in the world of life, parasitism is a mortal one, and the transition is tragically easy. These are truths of profound origin, and therefore of wide application. They apply not only to the "partnership" of alga and fungus upon a rock, but to every partnership between man and man, or man and woman. If marriage is a symbiosis, it is a vital triumph; if it is a parasitism, it will be a mortal failure.

The Changes Made in a Countryside by the Planting of the Scotch Fir

But there are countless relations between species, determining their lives, other than that which we call symbiosis. Darwin noted many striking instances in his early work. Thus, he observed how, in Staffordshire, the introduction of a single tree, the Scotch fir, had changed the number and character of the living species upon the heath where they were planted, as compared with the unplanted part of the heath. The change in the vegetation, on passing from the one to the other was "more than is generally seen in passing from one quite different soil to another." The proportions of the heath plants in the planted part were quite different; many species of plants were found in the plantations and not upon the heath; six insect-eating birds were found in the plantations, and not upon the heath, which had two or three distinct insectivorous birds. Near Farnham, in Surrey, Darwin again studied the associations of the Scotch fir, and there he found that cattle absolutely determine its existence. All over hundreds of acres of unenclosed heath, he found tiny seedlings of the fir, which had been perpetually browsed down by cattle. One little tree, "with twenty-six rings of growth, had, during many years, tried to raise its head above the stems of the heath, and had failed. No wonder that, as soon as the land was enclosed, it became thickly clothed with vigorously growing young firs."

How Insects May Control the Existence of Cattle

Then we learn that, while cattle can control the Scotch fir, in many parts of the world insects determine the existence of cattle. Thus, in Paraguay there is a certain fly, an enemy of cattle, horses, and dogs, which are thus kept down, though north and south of Paraguay they run wild. These flies are themselves checked in numbers by other parasitic insects. Hence, if certain insectivorous birds were to decrease in Paraguay, the parasitic insects would probably increase, which would lessen the number of flies, thus increasing the number of cattle and horses, with the result that the vegetation would be markedly altered. But this alteration would profoundly affect the insects which live upon the vegetation, and thus the birds which live upon those insects. Thus, we are back to the birds with which we began, and this case suggests the complexity of the balance of Nature in high degree. We might think it a rare and peculiar one, but Darwin closes his discussion of it with these weighty words, never more pertinent than today.

"Not that under Nature the relations will ever be as simple as this. Battle within battle must be continually recurring with varying success; and yet in the long run the forces are so nicely balanced that the face of Nature remains for long periods of time uniform, though assuredly the merest trifle would give the victory to one organic being over another. Nevertheless, so profound is our ignorance, and so high our presumption, that we marvel when we hear of the extinction of an organic being; and as we do not see the cause, we invoke cataclysms to desolate the world, or invent laws on the duration of the forms of life."

Darwin's Interpretation of the Balance of Nature Justified by Every Modern Discovery

It is impressive to return to these words, written more than half a century ago, in the light of our modern knowledge regarding cattle and insects. Today every reader of newspapers knows something of the relation between the tsetse-fly and the survival of horses, the manner in which a relative of the tsetse-fly acts as host and vehicle for a minute animal parasite which causes sleeping-sickness in human beings when that fly bites them, and the recent and remarkable evidence which suggests that the crocodiles and big game in Africa may be largely responsible for the existence of the dangerous flies in question, which live upon their blood in the absence of man. Most of us have vague ideas, also, as to the part played by vegetation in this problem, for it is the lake vegetation that houses the flies while they wait for cattle or man to go to the water; and we know how similar relations and complications arise in the case of many other diseases,

such as malaria, which will ere long demand special study in this place. Everything that Darwin saw and foreshadowed in this direction has been many times over confirmed since his day. His acute observation and interpretation of the balance of Nature and the astonishing relations between species "in ever-increasing circles of complexity" are justified by every modern discovery in the realm of tropical disease and of disease at home. He has prepared the way for our minds to appreciate the fact that man is simply one of the species concerned in these immeasurably various and complex cycles, and that what we call disease in him is simply, in most cases, an aspect of the balance of Nature and the struggle for existence, as Darwin first clearly perceived and defined them more than fifty years ago.

Further, we begin to realise the full weight of his words when he says that the balance is usually so delicate that the merest trifle would give the victory to one organic being over another.' Man is himself the persistent and incessant disturber of the balance of Nature.

The Balance of Nature Disturbed Mostly by Men

He keeps on introducing a novel species—namely, himself—into all parts of the world. He introduces vegetation and destroys it. He cuts down forests, diverts streams, makes canals, builds cities and slums, takes the rabbit to Australia, exterminates his fellows here and there, in places where they have, by long evolution, become well balanced with the rest of the living species there residing, and substitutes forms of human being evolved under other skies and with different powers of resistance. The consequences are colossal. All manner of "new" "diseases" appear, because the balance of Nature has been disturbed, and this or that species, long kept under, finds itself in a very paradise of food and opportunity—like the tubercle bacillus in the "Paradise Alley" of many a slum.

All these facts and problems must henceforth be looked at biologically, through eyes which Darwin has taught to see, and in terms of the warring, hindering, helping, elbowing lives of species, high and low, man, mouse, mould, microbe—all striving for life at all costs, and playing into each other's hands, or utterly annihilating each other, as the conditions of the struggle may determine. To understand those conditions, and thereafter to control them in the interests of his own species above all others, is the urgent task of man.

One more illustration must here be quoted, for Darwin has made it classical, and many are familiar with it who know nothing of the great principle which it illustrates, and which we now see to mean vastly more for the life of man than ever Darwin could guess. The humble-bee was proved by Darwin to be necessary for the fertilisation of the heartsease and certain kinds of clover, which other bees do not visit, as they cannot reach the nectar. And here is Darwin's famous conclusion.

Darwin's Illustration of the Dependence of Red Clover on the Domestic Cat

"Hence we may infer as highly probable that, if the whole genus of humble-bees became extinct or very rare in England, the heartsease and red clover would become very rare, or wholly disappear. The number of humble-bees in any district depends in a great measure upon the number of field-mice, which destroy their combs and nests; and Colonel Newman, who has long attended to the habits of humble-bees, believes that 'more than two-thirds of them are thus destroyed all over England.' Now, the number of mice is largely dependent, as everyone knows, on the number of cats; and Colonel Newman says, 'Near villages and small towns I have found the nests of humble-bees more numerous than elsewhere, which I attribute to the number of cats that destroy the mice.' Hence it is quite credible that the presence of a feline animal in large numbers in a district might determine, through the intervention, first of mice and then of bees, the frequency of certain flowers in that district."

Parasitic Warfare Between Beings Wide Apart in the Scale of Nature

One final sentence from our great teacher must be exactly quoted, and then we may pass on to the conditions of the problem as it faces us today. He concludes his wonderful study of this subject with the words: "The dependency of one organic being on another, as of a parasite on its prey, lies generally between beings remote in the scale of Nature."

What a significant and profound anticipation, as if seen with the prophetic eye, of what was about to come—the work of Pasteur and his pupils, the discovery of the microbic nature of disease, the work of Manson and Ross on malaria, its parasite and its mosquito, and all that is even now being added to these great achievements!

PLANTS POISONOUS TO ANIMAL LIFE

DEADLY NIGHTSHADE

THORNAPPLE

HENBANE

BARBERRY

MONKSHOOD

HORSETAIL

FENNEL

HELLEBORE

RHODODENDRON

THE DEFENCES OF PLANTS

How Plants that Live Near the Ground Ward Off Their Enemies with Poison, Dagger, and Subterfuge

THE STRUGGLE WITH THE ANIMAL WORLD

In the world of animate Nature, so long as things are not interfered with by man, the general rule of life is that the race is to the swift, and might is right. All observations upon living creatures in a state of nature impress upon our minds forcibly the conclusion that the struggle for existence is a great reality, and none but the fittest survive. True, there are examples of plants and animals living more or less in dependence one upon the other, but even in such instances the benefit derived is usually for one of the individuals at the expense of the other. The broad, true statement remains—that plants and animals make no effort to help any but themselves. Altruism is the last product of human, ethical progress.

This being so, and granted that the evolution of plants and animals has proceeded through the ages on the lines of natural selection of the fittest to survive, it can be understood that, in the case of plants especially, what constitutes the fittest will frequently be some special means by which the plant can protect itself against attacks from all sides. Unfortunately—from the point of view of the plant—the flora constitutes the principal source of food supply for the animals, and the plants are therefore in a constant state of exposure to risk of life and danger of extermination. Other dangers, too, have to be faced besides that of consumption for food, but that in itself is such an important matter that for the moment we may confine our attention to it.

In an earlier chapter we paid some attention to the composition, from the chemical aspect, of plant structures, and we noticed amongst other things that chlorophyll granules have a very similar composition to that of protoplasm; moreover, by their action, sugar and starch are manufactured, and the cells containing the green colouring matter also contain easily digested carbohydrates. Now, it just happens that these are precisely the kind of foodstuffs upon which the herbivorous animals subsist. Moreover, the herbivorous animals choose for their special food principally the chlorophyll-coloured tissues. It is here we see the incessant battle for existence between the plant and animal worlds. The animal, presumably, merely acts upon the instinct of hunger, and has not the foresight to reason that the result of his indiscriminate feeding upon the green parts of plants will destroy their capacity for producing food afterwards. Man acts somewhat differently, because, although he destroys very large quantities of green plants for purposes of his own, he usually leaves enough either of the individual plant or a sufficient number of individuals to replenish what he has taken for himself. But this protection meted out to plants by the reason of man is, after all, only extended to a very few species namely, those which he himself requires for his own food or clothing, or for some other product in civilisation. If nothing else existed to save the plants, man's foresight would be unavailing, because so few of them, comparatively, interest him in a sufficiently practical way. The plants are therefore thrown back upon themselves for protection, and hence there have been evolved a variety of structures and processes that may be summed up in the term "plant defences."

Plant defences are of very different kinds and degrees. Some of them secure the plant absolutely from almost any sort of attack, while others merely enable them to attain relative immunity. Other arrangements are not merely protective to the plant itself, but are of deadly danger to those whose temerity prompts them to interfere with it.

Amongst the more formidable plant defences *poisons* at once occur to the mind; and it is interesting to note that most of the plant-poisons are found only in those portions of the plant where they are necessary for protection. That is to say, plant-poisons occur chiefly in the leaves, the flowers, and the fruits. Another point to be kept in mind is that the different poisons secreted by the plant do not all act to the same extent upon all animals. For instance, the leaves of the common deadly nightshade (atropa belladonna) are very poisonous to the common domesticated animals of the field, and yet these very same leaves are the food upon which one of the beetles flourishes. By marvellous instinct the larger animals will avoid this plant, but by a similar instinct the beetle seeks it out for food.

So here we have the curious case of a plant protected against external enemies by its leaves containing a very deadly alkaloid, while, at the same time, the plant can supply small parts of itself for food to a tiny beetle without being entirely sacrificed. The beetle merely eats a few holes in the leaves; it does not destroy the plant.

How do Animals Know How to Avoid Injurious Plants?

It is very difficult to imagine how animals become possessed of the knowledge which enables them to avoid such plants as the deadly nightshade. We say that it is in virtue of their inherited instinct, but how that instinct became evolved in these definite directions is not quite so easy to demonstrate. This, however, is not the place to discuss that topic.

In some cases poisonous plants have quite a distinct smell, and we can understand how they may be readily avoided. For instance, the thorn-apple, the common henbane, and the hemlock have leaves the odour of which is distinctly disagreeable to the taste. But in quite a number of other cases no smell is obvious to man until the leaf becomes bruised, yet these plants are just as carefully avoided by the animals of the field as is the more obviously dangerous group. In this last category may be placed the monkshood, the black and the white hellebores, and the meadow saffron. None of these is ever eaten by wild animals such as hares and deer, and all are carefully avoided by the domesticated animals of the farm, not excepting even that least particular of animals the goat.

These plants, as we have said, have no obvious odour—to us, at any rate—but it is, of course, possible that the more delicate sense of smell in the lower animals is sufficient to warn them of the danger. A further interesting point is that there are quite a number of plants not poisonous to man, but most scrupulously avoided by the herbivorous animals. In this list may be placed a number of mosses and ferns, and the greater plantain. Since these are so carefully avoided, the presumption is that they would be injurious to the animals if partaken of. So that first and foremost amongst the defences of plants must be placed the possession of poisonous qualities.

The Indisposition of Animals for Feeding on Plants Impregnated with Salts

Many plants have leaves so impregnated with salts of one sort or another, or mineral matter, that they are either distasteful to animals or extremely indigestible. In the leaves of the horse-tails, rhododendrons, and many of the evergreens found on moorlands and hills there is such a strong deposit of silica that they are not tempting morsels of food. The same is true of the plants composing much of the flora of the Australian bush.

One would not imagine at first sight that the presence of water would have the protective power in connection with plants, but there is one connection, at least, in which water is a protection. Grazing animals do not care to feed upon plants on whose leaves drops of water or dew are actually present. In response to this example of the immunity conferred upon such plants, some have developed quite a special capacity for retaining water in the form of dew. One such plant takes its name, the dew-cup (otherwise the lady's mantle), from the very fact of its leaves being so shaped that both rain-water and dew are retained at the bottom of the leaf in a little kind of cup, or well, long after evaporation has dried the leaves of other plants in the immediate vicinity.

The Many Forms of Prickle Evolved as a Defence

We next may turn attention to plant defences in the form of weapons of armour, so to speak, structures exhibiting a distinctly threatening appearance, as if they said quite plainly: "Let him touch who dares." In this group we have the array of spines, prickles, and thorns characteristic of so many plants. The distinction between these several defences is that the spine is composed of actual wood, terminating in a sharp point; the prickle, on the other hand, is merely an epidermic structure, and contains no wood, though it ends in a point that is always strong enough to produce

PLANTS WITH WEAPONS TO WARD OFF FOES

SEA-HOLLY

SOW-THISTLE

FURZE OR GORSE

HAWTHORN

COLLETIA

SPINY OPUNTIA

BERBERIS

ALOE

DWARF THISTLE

injury. Now, although all parts of a plant may possibly be more or less protected by spines or prickles, it will be found that they are especially arranged to protect the green leaves. If not actually on the leaves themselves, they are on those parts of the plant with which any animal attempting to injure the leaf would come in contact. The detailed position and size of these various protective structures evidently depend upon the kind of animals whose attacks are most to be feared, and the way in which the attack is likely to be delivered. So we find that the huge floating leaves of the *Victoria regia* are only protected on the under surface and at the margin, because only at these points are they liable to attack. Other plants are well protected during their infancy, so to speak, that being the time when they are most susceptible to danger. Once they reach such a height as to be beyond the reach of the mouth of the grazing animal, the thorns disappear.

The arrangement hinted at above would show that some plants restrict their protective weapons actually to the site of danger, while others distribute their weapons in such a way that one part of the plant protects another, or the whole plant. Some, of course, such as the furze, are so spiny as to have a distinctly formidable appearance. Certain of the leaves have a number of little, sharp points projecting from the network; others carry their armoury at the margin, and these different structures, most of which are strengthened with silica, take the form of either prickles, or hairs, or bristles.

The leaf itself may be in the form of a needle, in which case it is termed *acicular*. It is an interesting point to note in passing that not only are such leaves very similar to needles in appearance, but in such parts of the world as are destitute of more perfect implements they are actually used by natives as needles. Plants with leaves of this type are particularly characteristic of dry, arid wastes and deserts, where, owing to the extreme paucity of vegetation, the green-leaf plants are subject to the attacks of animals. The highlands of Mexico are specially prolific in plants whose leaves terminate in a prominent thorn. These thorns are capable of inflicting extremely serious injuries upon any animal coming in contact with them. Other forms, like that of the aloe, occur in South Africa. In all of these cases it is the leaf itself which ends at its tip in a thorn.

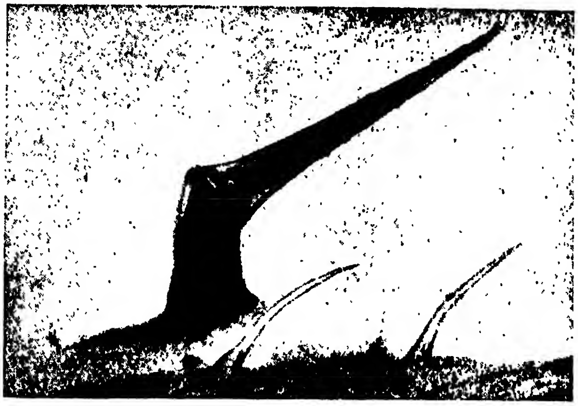
Another kind of defence is seen in the thistle, and plants of a similar nature. In them the leaves are all split up more or less, and have margins and ends with a very serviceable protection of spines. Plants of this kind occur in widely spread areas, but abundantly in the Mediterranean countries. The result of the splitting up of the leaf is that there is not a great deal of green tissue left.


LEAVES OF THE SAME HOLLY TREE WITHIN, AND OUT OF, THE REACH OF CATTLE

Arising from the actual surface of the leaf itself, as opposed to its point, we have the weapons in the shape of bristles, or barbs, whose points are generally very hard, from the presence of silica. A leaf the margin of which is protected in this way may be aptly compared to the edge of a saw with its teeth; and not only so, but it may actually be used in a precisely analogous way. One can easily imagine how such forms of green leaves would be distinctly distasteful to grazing animals, whose lips and tongues would readily be lacerated by such weapons. Some species of grass show blades so impregnated in this manner with silica as to be capable of inflicting very serious wounds if touched.

Everyone must have had experience of the annoying little weapons possessed by many leaves in the form of sharp-pointed barbs that stick into the skin when the hand is brought into contact with the leaf. A variety of this kind of protection is seen to perfection in our own common indigenous nettle. The weapon here takes the form of a stinging hair composed of one large cell, which readily breaks off and leaves a

portion of itself attached. A very slight contact is sufficient to break such a hair, and the fracture leaves behind it an extremely sharp-pointed portion, from which exudes an irritating substance of the nature of formic acid, and this is injected into the skin of the animal or person handling the leaf. The process is very similar to the arrangement of a hypodermic syringe. Considerable inflammation may be caused in the skin as the result of the breaking off of a number of hairs in a small area and the injection of their contents.


THE STINGING HAIR OF A NETTLE
This highly magnified photograph shows the hair in a single cell filled with protoplasm and acid sap, which flows out when the bulb at the tip is broken.

Everyone is familiar with the fact that if the nettle be handled in a certain manner these unpleasant effects may be avoided. It is possible to stroke a nettle with one's hand without being stung. For one thing, the lower part of the plant has no stinging hairs upon it. They are restricted to the foliage leaves. The hairs themselves are distinctly elastic, and can be pressed down so as to lie in close contact with the surface of the leaf. If, therefore, one grasps the nettle from below, and passes the hand upwards so as to press down the hairs on to the leaf, the hand will glide over them without causing any break in the hairs, and therefore without sustaining a wound.


THE STINGING NETTLE AND ITS MIMIC, THE RED DEAD-NETTLE

But, on the other hand, if the hand comes down on the leaf from above, the slightest touch breaks off the points of a number of the hairs, which pour out their poisonous contents. Here we have an excellent protective arrangement, therefore, against the depredations of grazing animals.

Thus far, then, we have seen that plant defences may be in the nature of more or less offensive smells, which create a distaste in the animal for whom otherwise they might form food. The dog-fennel and the hound's tongue are plants whose smell is evidently much disliked by ordinary grazing animals. Secondly, we have noted that there may be contained in the leaf of a plant, as well as possibly in some other parts of it, some extremely poisonous principle, generally in the nature of an alkaloid, as we get it in the hemlock and the tobacco plant; and here, too, there is sometimes an odour associated with the plant which warns the animal of its nature, though sometimes the plant is odourless. Further, a great many plants have an extremely bitter, sour, or acrid taste, quite sufficient to keep animals from troubling them. The leaves and shoots of the horse-chestnut and the maple are of this nature, and are sedulously avoided by most animals, and even by insects.

Not only the leaves, however, are thus protected, because when one considers plants such as the potato, the peppers, mustard, and horseradish one sees at once that different parts of the plant, or, indeed, almost all of it, may be distasteful. In certain plants smell and taste combine to produce their effect, and this is probably the case in many of the bulbs, like the onion. Then we have seen that plants in arid and desert places are principally protected by the presence of extraordinary

developments in the nature of thorns or cutting leaves. Also, we have noted that a large number of our own indigenous plants are provided with thorns (excellently seen in the barberry), or they have pointed, barbed, stinging hairs. A still further protection is conferred upon such plants as have hard, flinty stems, or very silicious leaves, both of which are indigestible.

Plant defence, however, is not entirely a question of the provision of actual weapons. The plant is still not quite at the end of its resources, and may even turn to subterfuge, as it were, to protect itself. Thus we have very curious examples of what is termed *mimicry* in plants, the evident object being to suggest such a striking resemblance to something else as will cause the imitator to have his identity mistaken. Perhaps the best-known example of this process is that of the common dead-nettle. It takes this name from the fact that in general appearance it looks extremely like the common stinging-nettle, though, as a matter of fact, it is quite devoid of any such unpleasant properties. Doubtless, however, the likeness is sufficiently close to secure considerable protection. Some plants in South Africa have been noticed to grow extremely like pebbles, whilst others are coloured in a strikingly protective way to resemble the earth.

THE CATCH-FLY AND ITS VICTIMS

More peculiar still are the arrangements for self-protection in what are called the ant-plants, offering special inducements, as it were, to the ants to establish themselves upon these plants, or, rather, trees. True, some ants live upon vegetable food, but the great majority are animal-eaters, and destroy large numbers of insects. This property of the ants has been turned to practical account by orange-growers in China, who deposit ant-nests in the orange trees, and construct bamboo bridges from one tree to another in order to allow the ants to pass.

A striking arrangement of this sort is to be found in an acacia, which provides special food for the ants at the end of its leaflets. The ants living on this material protect the leaves from any further attack. Indeed, the number of plants with some sort of arrangement of this sort in order to attract ants, and thereby incidentally to repel other insects, is extraordinarily large. This kind of relationship between a plant and an animal for their mutual benefit is termed *symbiosis*. Such a plant is said to live symbiotically with these ants, the plant providing a lodging, together with nourishment of a sugary and albuminous nature, and the fierce little ants providing a standing army against caterpillars, beetles, and snails. The actual protection is carried out by the ants hurling their excretion of formic acid against the unwelcome visitors.

The gardener wishing to protect a plant from the various smaller enemies of the animate world will sometimes surround his plant with water, standing the pot containing the plant in another containing the water, and so preventing the access of any insects that are not prepared to fly or to swim. Now, this isolation by means of surrounding water is, of course, found in the case of many water-plants, such as the water-lilies, and innumerable others, whose situation confers upon them an almost complete immunity from dangerous attack. The visitors that arrive in their search for honey and pollen only serve the useful purpose of fertilisation, while the injurious insects, such as the snails, etc., are effectively warded off. The same principle—though, of course, on a much smaller scale—is to be observed in plants which allow a slight portion of water to accumulate at the base of their leaves.

More common than even this last scheme is a mode of defence specially provided for the benefit of the flowers. We refer to the presence of extremely sticky secretions. Sometimes this secretion, which is excreted by the plant tissue, lies upon the surface, and

entirely precludes insects from crawling over it. The sticky excretion often comes simply from the epidermis, and in other cases from special glands or hairs The most common position for the protection of the flower is on the flower-stalk, or else the principal stem. A common example is to be found in the catch-fly, which takes its name from this very property. The protection derived from sticky secretions sometimes extends not merely to the flower, but to the whole foliage, as in certain of the primulas and saxifrages, on whose leaves the dead bodies of insects are frequently found adherent.

Then, also, it must be remembered that the wax-like covering, present in so many flowering parts, obviously is a means of protection to the flower from the entrance of insects. This, at any rate, is one part of its function. It is interesting to note, in passing, how varied plant defences are to meet the attacking forces. Thus, a waxy exudate is no protection against a snail, for it will pass over it without any trouble. On the other hand, it is perfectly effective in the case of the hard-bodied little insects. They find in it an insuperable barrier. Snails and slugs, however, are effectively warded off by anything in the nature of a sharp point, such as a thorn, for by it their soft bodies are readily lacerated.

A PSEUDO BULB OF AN ORCHID WITH AN ANT COLONY

When we come to consider the structure, nature, and function of the flower itself, we shall have to refer again to this question of defence in connection with special parts of a flower. It will be sufficient to say here that most of the plant defences, produced as protections against the winged insects, are situated inside the flower, and are in the form of hair-like structures, arranged in a number of different ways. Then, again, the actual arrangement of the flower structure itself, especially as it affects the hiding and protection of the honey, is often extremely ingenious.

Lastly, we may refer to the mechanical arrangements devised by plants to protect their stems and leaves against insects which would creep up them from the earth. One of the most ingenious of these arrangements is that occurring in some of the balsams, in which the honey secreted by the leaves, or in their vicinity, obviously protects the honey of the flower itself, this flower-honey being required to attract fertilising agents. There is a special gland developed from the stipule at the base of the leaf, which secretes the honey and attracts insects on their path upwards. They come in contact with a drop of honey at the base of every leaf, honey as good as that found in the flower, and closer at hand. Ants, therefore, in search of honey, go so far, and no further. In the absence of such provision, they would, of course, search out the honey within the flower itself, and would thereby interfere with the visits of those winged insects whose arrival is necessary in order that pollination may be effected and the plant's spread extended.

Then it must also be remembered that all the many and varied devices to be found in plants, by means of which insects are attracted and guided to different portions where they find food provided for them; all the various arrangements of petals, which assist in cross-fertilisation; all the manifold provision for the dispersion of seeds and fruits; all the protective structures of seeds and fruits, as well as an infinite number of other considerations, might very well be regarded as coming under the general heading of plant defences.

A REMARKABLE STUDY IN BIRD-LIFE OF PARENTHOOD UNDER UNFAMILIAR CONDITIONS

▲ RECONSTRUCTION OF A COLONY OF FLAMINGOES IN THE BAHAMAS AT THE AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK
The photographs on these pages are by Messrs. L. Medland, W. Bickerton, Oxley Grabham, P. Parkin, B. Hanley, and others.

FAMILIAR BIRD FAMILIES

Interesting Birds Whose Families Visit This Country, or Have Visited It in the Past

THE DIFFICULTY OF CLASSIFYING BIRDS

Having dealt so far with birds mainly British, we must extend our horizon to include examples of more generalised distribution. Many of them have their British representatives, but others have not. We can but select arbitrarily, and must withstand the temptation to follow out the fascinating problems of avian life which threaten to lure us from the strait way of descriptive enumeration. The bustards serve for a jumping-off point, and at once the student finds himself confronted by a theme of infinite interest.

The bustards, it is now found, are specialised descendants of the crane tribe. Well, are the cranes not modified storks? Science today answers in the negative. They are allied to the plovers, and so are the fowl tribe. The fields must be robbed of some of their most potent of insect-enemies in order that the wealthy may have plover eggs upon their table, though poultry eggs by the million are available. It is not a little diverting that the exalted palate, which would revolt at the thought of eating the egg of a carrion-feeding gull, does in reality eat the gull's egg, disguised as that of the plover. Well, gulls and plovers have a common ancestry, so in a sense the gull's egg is a plover's. That, by the way.

Here we have this great assemblage of birds, the bustards, spread over a great area of the earth, the cranes equally widely distributed, the plovers legion in number, and scattered over half the earth, and the fowl of the jungle developed into breeds innumerable. Of the four groups, man has taken in hand only one, the jungle fowl. The story of that marvellous chapter of evolution is told in a glass case at our Natural History Museum. We see that insignificant-looking jungle fowl which, when the directing hand of man was first applied, represented the only breed of fowls in the world. The rest of the story is for the fancier and the poulterer, told in the thousand books and periodicals which are his. Other members of the group have been left untouched; and it is to be admitted that the results of natural selection have been less wonderful than those attending artificial selection.

The bustards are about forty species strong, but not one of these species can now obtain a foothold in Great Britain. The typical species stand from three to four feet in height, as to the males, while the females are some nine inches less. Once we had swarms of these interesting birds, but the cultivation of the wild lands they haunted, and, still more, the execution wrought by the savage with the gun, have made the birds practically extinct as a British species; and we never hear of a bustard in England except through the agency of a news paragraph which tells of the shooting of one of the very few that do arrive.

Seeing that seventy years have passed away since bustards were recognised in numbers in England, it is a puzzle as to how we get the few that do still at rare intervals visit us. Does accident bring them—an adverse gale, or loss of the bird's bearings when in flight? Or can it possibly be the result of persistence of instinct in descendants, all these generations removed, of the stock which once was ours? Grain-eaters, able to subsist on herbage and young shoots, with a penchant for insects and small reptiles and mammals, the bustard should have an excellent chance of life with us still if only the man with the gun were manacled; and if our old-fashioned typical bustard and the little bustard that used to visit us, share, as there is every reason to believe that they do, the fondness of the African, Indian, and Australian long-beaked bustard for rats and mice, they would

be welcome allies in our national campaign against those hateful rodents.

Our bustards, as we may call them, are noted for the famous displays made by the males during the breeding season, but they lack the splendid colouration of plumage which marks the nuptial dress of the male florican, an Indian ally of the bustard. The thicknees, which still frequent our heaths and open lands in summer, ought to be protected for the same reason as the bustards. Wonderful as is their power of concealment, thanks to resemblance to their surroundings, they are handicapped by the fact of their making simply a depression in stony ground for their two eggs. To human eyes this "nest" is practically invisible, owing to the stony look of the eggs; and if a bird be disturbed, it runs from the nest, and, sinking down, with neck outstretched along the ground, presents the appearance of a small boulder. Even so, there are many dangers for the thicknees, so that the bird has become nocturnal in habits, a fact which is of importance, inasmuch as mice and voles are a considerable part of its food.


THE SUN-BITTERN DISPLAYING


THE BUSTARD DISPLAYING

Whither next? the ornithologist must ask himself, and the doubtful answer is "the seriemas and trumpeters." These are singular South American birds, which, originally claimed as allies of the secretary bird, are now found to be more nearly associated, by anatomical structure, with the bustards and cranes. Nobody can place them exactly. The vulture-like features of the beak, the resemblance of the plumage and carriage to those of the secretary bird, render the question of relationship very puzzling; for, as the two birds are occupants of widely separated continents, there can be no question of mimicry. The prey of the seriema consists largely of snakes and lizards, and for this reason the bird is zealously protected in Brazil. Young seriemas have been hatched in the Zoological Gardens at Regent's Park, but they have simply formed a meal for the parents, so we have little knowledge of the youth of these birds.


THE THICKNEE AND ITS TWO EGGS

The trumpeters, which have been described as a guinea-fowl set on elongated legs and equipped with a vulture-like beak, are distinguished by the long, trumpet-like call-note which they utter. Those who have studied the vocal organs of birds find in the trumpeter one of interest, for correlated with its remarkable voice we find a windpipe elongated so as to extend under the skin of the abdomen. The trumpeter is tamed by the Brazilians, who find it a good guardian against birds of prey and other enemies of domestic poultry.

The cranes come next, being, as we have seen, removed from the classification which arrayed them with the storks, and divided also from the herons, to both of which they present an external resemblance. They are placed today with the birds we have just been considering. There are nearly a score of species, mainly belonging to the Old World, for South America, in spite of seriema and trumpeter, has not a single true crane. Their home is made in wide plains and marshes, and their nests are roughly built on swampy soil. It was the European species, a fine bird, measuring from 40 to 48 inches, which, up to the seventeenth century, bred regularly in England, but it is now among our rarest visitors. We cannot

hope to restore it. The bird is so wary that it will not approach any spot in which the least shadow of danger may be supposed to lurk. We have not now a sufficient range of territory quite safe from menace by which to lure it back. It would be easy enough for them to reach us, for the flight of the crane is powerful and sustained, as it is majestic and graceful. In the course of their migrations the birds cover great distances; and the skilful ordering of the flight, vast companies of birds flying in V or W shaped formation, each column under the guidance of an experienced bird, has formed the subject of many an observant naturalist's word-picture.

The breeding grounds of the cranes extend from the Arctic Circle in Western Siberia, to Italy and the Danube, but the bird is to be found at various times over nearly the whole of Europe, Central and Northern Asia, visiting India, Persia, South China, and Northern Africa, and even crossing Japan in the course of its migrations. But to England it comes not again. Beauties such as the demoiselle, the white crane, the Stanley crane, and the crowned cranes we never could hope to have, but we may still sigh for the European species that once was ours.

South America, which has no crane, has closely allied birds in the courlan and the kagu, while Madagascar has, in the mesites, a distinct species which, resembling the crane, possesses the remarkable powder-down patch of the heron, to which a relationship is suggested, though cranes and herons are not related. The delightful sun-bittern is regarded, too, as an aberrant crane. The sun-bitterns are remarkable as being the only birds of the group that have helpless young. These birds derive their name from their love of basking with plumage outspread in the sun. They are peculiar to South America, where they frequent the wooded banks of rivers, depending for food supply upon insects. Their displays as they enjoy the sun resemble that of other birds showing off their nuptial plumage, but many British birds—notably the goldfinch and chaffinch—make similar, if less picturesque, displays when a burst of sunshine follows a period of dull weather. The sun-bittern's flight is compared to that of a broad-winged butterfly—a sufficient testimony to its beauty.

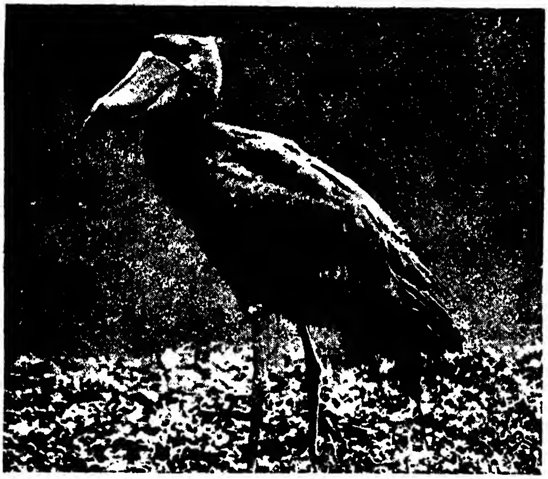
EUROPEAN HERON IN FULL PLUMAGE

THE LITTLE EGRET

To find the true bittern we must retrace our steps, for it is placed among the heron tribe, a group of birds scattered all over the world, save in the extreme North and farthest South, and numbering fully seventy species. Some of them are among the most conspicuous beauty-birds of marsh and swamp of tropical and sub-tropical lands, but their range includes many conditions, and their numbers such widely different types as the beautiful little egret and the repulsive adjutant storks. Formerly the heron was protected by law in our land, for the kings of that time loved to go hawking, and a heron was deemed the bird of birds at which to fly. Hawking is out of fashion now, and the heron no longer enjoys protection. Game-birds, waiting to be shot,

must not be slain by plebeian hands; but as no one wants to fly a falcon at a heron, those who will may kill. There is a strange residuum of savage blindness in us.

Happily, there seems to be a possibility of a future for the heron with us again. A heronry gives "tone" to a country estate, it conceivably adds to the selling value of a place, and there is undoubtedly growing up a spirit which makes for the provision of sanctuaries for birds. But we shall never see our prized birds numerous so long as it is necessary to establish sanctuaries within ring fences. Marshland and fen are not as extensive with us as they were, and the area must diminish; some of our richest land is that reclaimed from former wastes of this type. But there is space enough for the herons if the man with the gun, and notably that intolerable fool the uneducated gamekeeper, be but schooled aright. The heron haunts swamp and marsh, inland lake and mountain stream. Its diet is carnivorous. It takes fish, frogs, rats, mice, occasionally a young rabbit, and even insects. It will help to clear a ploughed field of mice; it will thin out the coarse and small fish of a trout-stream. It is not an enemy to the trout-fisher, for it will not take the big fish unless actually compelled by stern necessity. But typical of what happens is the incident narrated by Mr. J. A. Owen, in a readable chapter on the subject. A keeper shoots a fine heron which has been feeding on the shore, and Mr. Owen asks him what he does with such birds. "Nails 'em up on the side of the barn along o' the hawks and owls, because, don't you see, in my mind they belongs to the birds o' prey. If they don't, they ought to; they kills anything, so I'll do for they." And that is the stamp of man who has our beautiful feathered visitors at his mercy!



THE WHALE-HEAD

Before we can hope to preserve the remnant of our avifauna we shall have to establish a school for landowners about to engage gamekeepers, and make these gentlemen aware of what bird-life means to the men and women among us who do not desire these creatures simply for slaughter, and then hold them responsible for the acts of the sanguinary Goths whom they employ.

Among the most common of the herons are the European and the purple, both of which visit us, though the purple bird is now seldom seen. A larger and rarer heron is the famous goliath, the largest of true herons. A bird larger than the European species is the great white heron, a truly noble bird, famous for its beautiful white plumage and the exquisite, plume-like feathers of the back. These latter are developed only during the breeding season. The same remark applies to the aigrette of the little egret. The latter bird comes as the rarest of stragglers to Great Britain, but its home, like that of the great white heron, is in warmer climes.

THE BOAT-BILLED HERON

The white heron ranges through the South of France, Spain, eastwards through

Asia Minor, Turkestan, and the warmer parts of Asia, to Manchuria and Japan. It is migratory in the more northern parts, but

THE INDIAN ADJUTANT

THE GREAT WHITE STORK

resident in India and Burma and replaced by a slightly different species in New Zealand and Australia. The little egret is credited to South and South-Eastern Europe, and follows pretty much the line of the larger birds, but it is resident locally throughout Africa, whereas the great white heron winters only in the north of Africa. But vast as the range sounds, the birds themselves are fast disappearing. The infamous traffic in plumes for the bedecking of women's hats is rapidly extirpating these lovely birds. It is an old story unfortunately, and nothing need be added except this: The statement appears from time to time in the daily Press that exalted personages wear "artificial ospreys" in the hat. The so-called osprey is simply an aigrette. Now, the expert naturalists state that there is no such thing as an artificial aigrette; that the so-called imitations are the real thing; that the mock aigrette is the "Mrs. 'Arris" of millinery, and simply does not exist. Every aigrette sold means that parent and nestlings have perished. The aigrette is ripped from the parent bird, whose little ones are left to die of starvation in the nest. It is the women who are responsible for this outrage, for, without their custom, dealers in these plumes would have no market. It is to be feared that the experience of a member of the Royal Society for the Protection of Birds, a well-known woman in society, who had to deal with one of these callous creatures who wear the nuptial plumes of birds, was not exceptional. Her words on the subject were heard without comprehen-

THE SACRED IBIS

sion for a while, and then the reply came: "Oh, you are talking about my feathers? Well, then, let me tell you that I don't care one little —— about the birds!"

Another notable heron is the buff-backed, a familiar sight along the banks of the Nile, where it is commonly mistaken for the sacred ibis. It is notable as a snapper-up of field pests, especially of locusts, and by its attention to these latter must help to stay many a plague. The squacco heron links the former species with the true herons, and not seldom visits the British Isles, where it has been found in districts frequented by the night-heron, the small heron which has been driven to shelter by day either in thickly wooded country with access to water, or, preferably, in swamps and marshes, and issues, when darkness falls, to collect its prey of aquatic insects, molluscs, worms, frogs, and small fish. The gap between the night-herons and the true bitterns is bridged by the little bittern, a smaller edition of the bittern proper. It is the smallest member of the heron tribe to land upon our own shores, and is but a rare visitor. We are more favoured by the true bittern, but even this bird no longer nests with us today as a regular thing. Drainage and cultivation are held to be in the main responsible, but there remains always the man with the gun to slay the casual comers who might again make their home with us.

FLAMINGOES, CRANES, AND DUCKS IN THE AVIARY OF THE MAHARAJAH OF JEYPORE

The bittern, with its mottled plumage of buff, brown, and black, its long, pointed beak, and relatively long legs, is conspicuous enough when removed from its natural surroundings, but at home, among reeds and the dead stems of other vegetation, it is marvellously adapted for protective purposes. Unless summarily flushed from its hiding-place, it will stand still and rely upon its deceptive appearance, or, if it flies, it will not fly far, but drop and trust to its ability to emulate the stump of some dead tree. Nobody has given us a more remarkable picture of the bittern in the act of hiding than Mr. W. H. Hudson. He describes a little bittern which he encountered in Argentina. The bird was only thirty or forty yards from him when he fired, and, thinking that he had killed it, he went in search. "It was an isolated bed of rushes I had seen him in; the mud below, and for some distance round, was quite bare and hard, so that it would have been impossible for the bird to escape without being perceived; and yet, dead or alive, it was not to be found." He sought in all directions for a quarter of an hour, and was about to give up the quest, when lo! there was the bird on a reed not more than eight inches from him. "He was perched, the body erect, and the point of the tail touching the reed grasped by its feet; the long, slender, tapering neck was held stiff, straight, and vertically; and the head and beak, instead of being carried obliquely, was also pointing up." The whole figure was the exact counterpart of a straight, tapering rush. Thinking that it was merely because the front of the bird was exposed to him, Mr. Hudson wondered why he had not seen the bird when walking round and round the spot as he had done. He stepped away to get a side view, but the bird still kept its rush-like front towards him. "His motions on the perch, as he turned slowly or quickly round, still keeping the edge of the blade-like body before me, corresponded so exactly with my own that I almost doubted that I had moved at all."

The boat-billed heron of South America, the whale-headed stork of a restricted part of Equatorial Africa, and the hammer-head are famous members of the heron tribe with which, although they are far from common, we are all familiar, owing to their peculiarities having made them favourite subjects for the camera and the brush, while, thanks to our Zoological Gardens, we are able to study the birds in the flesh.

HANDSOME DENIZENS OF THE MARSHES


THE DEMOISELLE CRANE


THE STANLEY CRANE


THE CROWNED CRANE


COMMON CRANES

Strange and bizarre, however, as is the appearance of the whale-headed stork, it is absurd to describe it as "the Zoo's ugliest bird," as was done when one arrived in London during the present summer. The whale-head is a paragon of beauty compared with some of the storks, notably the marabou, which is, with some of the vultures, amongst the most loathsome - looking creatures in existence. With its long, coarse, bare neck, adorned in front by a great, naked pouch, and with the coarsest, most tumbled of plumage, the marabou, or adjutant, is not only the largest but the most forbidding-looking of the entire stork family. Nothing comes amiss to the marabou as food, from the carcase of a large animal to the filthiest offal, and his appearance seems closely to reflect his habits. But all the storks are scavengers; and that with which we are familiar in European cities is as a rule treated with consideration and kindness in recognition of the value of its services. Every little Dutchman and every little Dane regards the good, white stork as the courier with whom the human babies travel to earth, and the subject of the charming old legend merits its friendly reception. But the stork publishes no guarantee as to what he will eat, or, rather, what he will refrain from eating; and visitors to European cities which he frequents should take note that a treasured puppy or kitten is a tit-bit to this member of the family Ciconiidæ. The tremendous journeys accomplished by the storks on their annual migrations are a matter of common knowledge. Unlike some of the cranes, they are said to be voiceless, and to communicate only by means of various snappings of the mighty beak. As against this, however, they say at the Zoo that the marabou stork will bellow during the breeding season.

A PAIR OF SPOONBILLS

The last group of the heron tribe comprises the ibises and spoonbills. Of these, the sacred ibis, long reverenced in Egypt, carved upon the ancient sculptures and interred with honour, is universally famous. Ibises number some twenty species; the spoonbills half as many. One ibis, the glossy, occasionally visits Great Britain, and the charming little spoonbill was formerly numbered among the residents, or nesting visitors, of Suffolk and Sussex. Both ibises and spoonbills frequent the margins of rivers and lakes, and feed upon small fish, crustaceans, molluscs, and the like.

WILD GREY LAG GEESE IN NORTH BRITAIN

Flamingoes, to which we next come, are placed today by naturalists with the geese and ducks—not, as formerly, with the storks and herons. The Persians were wiser than we when they named the bird long ago the red goose. In spite of the lovely rosy plumage, and the extraordinary, long, down-curved beak, the bird is more true to the Persian name than to the position in the table which our naturalists formerly gave it. The peculiar beak is, like the puffin's, one of Nature's after-thoughts, as it were, for the nestling flamingo is straight-beaked like the duck. The purpose of this lengthy, curved beak is

THE BLACK SWAN

RELATIVES OF FAMILIAR WATER-FOWL

THE NEW ZEALAND SHELDRAKE

THE MUSCOVY DUCK

THE MALLARD DUCK

THE SHOVELLER DUCK

THE BAR-HEADED GOOSE

THE LESSER SNOW-GOOSE

THE UPLAND GOOSE

THE SPUR-WINGED GOOSE

revealed when the bird is feeding in the water, whence it derives its food. The elongated neck of the flamingo is twisted so that, to obtain the small shellfish which constitute its food, and such vegetable matter as it takes, the upper half of the bill is turned downwards next the mud. Some seven species of these birds are known, and of these four are American; but the scenes, which have been so often described, of thousands upon thousands of flamingoes rising like great, rosy clouds into the air have the lakes of North-West India for their setting.

The curious discovery has been made that the colour of flamingoes fades in captivity, but that, by careful treatment—the admixture of a certain strong, but harmless, dye with their food—the colour may be retained, or the fading process so diminished as to be inappreciable. That is the American process; the English is to give the birds liberty in a large area, with access to a pond well stocked with the food that they require. There is then no need to "fix" the colours; they do not fade. Wonderful are the effects of fresh air and natural feeding, as every aviarist among us has found. Near allies of the flamingo are the screamers, birds matching a swan in size, but equipped with a hen-like beak, with formidable spurs upon the front of each wing, and, in one species, a slender, horn-like process, some six inches in length, rising from the middle of the head, and curving upwards and forwards. Although the feet of the screamers are not webbed, there seems no doubt that in the breeding season, at all events, these birds are thoroughly aquatic in habits.

A GROUP OF PELICANS

We must now glance briefly at a very large family, that comprising the swans, geese, and ducks. The first-named, although they are few in species, are very widely distributed, owing, no doubt, to their immense powers of flight. Superbly graceful on the water, and not unimpressive on the land, they are not least to be admired when in the air, though, owing to the height at which they fly and the hours they keep, few of us have the opportunity of witnessing their aerial evolutions. Two species, the whistler, or whooping swan, and Bewick's swan, are winter visitors to the British Isles, the former distinguished by its larger size and whooping note, and Bewick's identified by its inferior dimensions and changing note. The species resident with us is the domesticated mute swan, which, in the wild state, by the way, trumpets like the whooper. In spite of his beauty and majestic deportment the swan is a rather stupid bird, and in the breeding season so aggressive as to be dangerous to human beings. The black swan, which the ancients thought could not exist, is a native of Australia, and there is a black-necked variety in South America.

The geese, according to official classification, are a curious assemblage; for, while retaining the ancient terminology, we have a swan (Coscoroba), the Muscovy duck, the Indian cotton-tail, the comb-ducks, and the summer and mandarin ducks included in various sub-families of the goose family; and the Cape Barron goose forms another sub-family. Opinion is divided as to the propriety of this grouping, but the whole question of the classification of birds is difficult—indeed, almost chaotic.

Taking the typical geese we have a sub family which, with several allied genera, have an almost world-wide distribution. They are practically all vegetable feeders, so that the well-known grazing habits of the domesticated variety is an inherited, not an artificially developed, characteristic. All the domesticated stock is derived from the wild grey lag goose; a bird of powerful and graceful flight. It breeds today in a restricted area in the British Isles, and is common throughout Europe. Next we have the snow-geese, scattered all over North America; the Brent geese, circulating, for the breeding season, throughout Arctic Europe, part of Asia, and in Greenland,

and wandering for the winter to Great Britain and several European countries, and from Greenland along the Pacific seaboard as far as Lower California; the bernicle (or barnacle) goose, anciently believed to be derived from the ship-barnacle; the handsome red-breasted goose of the Siberian tundras; the knob-winged geese of Egypt and South America, and many others. The whole form a collection of confusing affinities and distinctions, so that naturalists cannot agree where swan ends and goose begins, or where to fix the dividing line between goose and duck. As the Coscoroba swan is included with the geese, so the Egyptian and knob-winged geese are included, with the tree-ducks or whistling teal and the sheldrakes, in the sub-family Anatinæ, typified by the ducks.

THE GOLDEN PLOVER

A PEEWIT ON ITS NEST

THE STILTED PLOVER

The tree-ducks are to be found throughout tropical and sub-tropical lands; and one species, it is interesting to note, is common to South America, tropical Africa, and Madagascar. As their name implies, they make their nests in trees; and it is fortunate for them that their flesh is unpalatable to man, so that they are not commonly killed for food, for they are indifferent fliers and dull, stupid birds. The handsome sheldrakes, which number six species, breed in Great Britain, and from their fondness of rabbit burrows as nesting sites are termed burrow-ducks.

As the grey lag goose is the ancestral form of all our domesticated geese, so the mallard, or wild duck, is the ancestor of domesticated ducks. "Mallard" is an unsatisfactory name for this bird, as it really means the male of the species, but, as it is the commonly accepted, specific title, it must serve. The mallard ranges throughout the northern hemisphere, and is of considerable utility in devouring vegetable substances which would choke watercourses. Similar is the distribution of the shoveller duck, but this is mainly a winter visitor to Great Britain, whereas the mallard nests here. For the pintail, the wigeon, the pochards, and scamp ducks, the mergansers, and other groups of this extensive family, the reader must consult a work devoted entirely to natural history. Here we must for a moment glance at a more famous water-bird, the pelican, the largest representative of an order which we partially surveyed in the preceding chapter.

THE AVOCET

A CURLEW ON ITS NEST

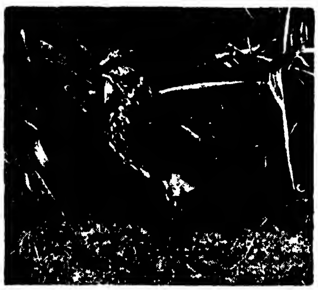
THE BLACK-TAILED GODWIT

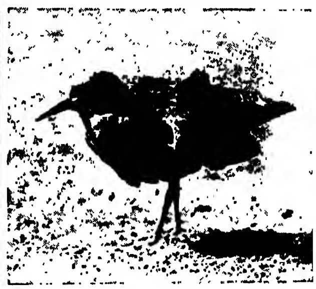
Although all the half-score species are now restricted to the waters of warmer latitudes, fossil bones in Norfolk and Cambridge

show that pelicans visited our islands in times of old, if they did not permanently abide here. All the species are remarkable for the bag-like lower half of the beak, forming a sort of bag-net, while the upper half constitutes the lid. This immense, dilatable pouch serves not only to receive the fish which the bird catches: it acts as a sort of trough from which the young help themselves to food regurgitated by the parent bird. Pelicans, which assemble in great flocks in the neighbourhood of swamps, estuaries, and rivers, are so numerous in parts of India that a reliable writer speaks of seeing *miles* of them at a time.

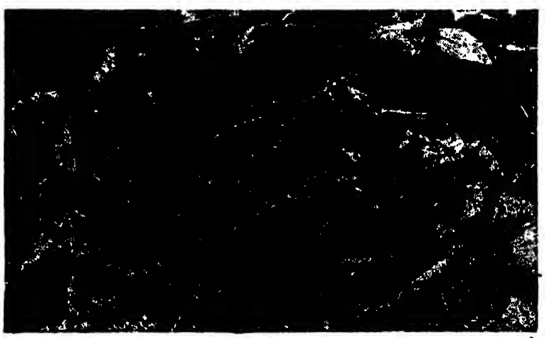

THE COOT SETTLING DOWN ON ITS NEST


THE RUFF WADING


JACK-SNIPE


THE KNOT

Having previously dealt with the gulls, we must briefly note another array of allied birds, the plover-like group, which, though allied, as we have seen, to the gulls, are grouped to constitute the limicolæ order. It comprises four distinct families, with upwards of two-score genera and many species, ranging from the pratincoles and coursers to plovers, lapwings, stilts, avocets, oyster-catchers, curlews, and wimbrels, sandpipers, ruffs, godwits, turnstones, knots, woodcock, snipe, jacanas, and water-pheasants, sheath-bills and seed-snipe—a formidable list, requiring many chapters if one would do it justice.


THE WOODCOCK ON ITS NEST

Bird-brains attain a high level in this order. The tricks of the lapwing to divert attention from its nest and young are famous examples of avian intelligence—the reeling in the air, the halting, limping flight along the ground as if wounded, all deliberately executed to lure the intruder from the nest. An example of solicitude, different in conception but equally admirable, is that of the sand grouse. These birds nest in parching deserts, but night and morning the male flies to a distant pool, slakes his own thirst, then immerses himself in the water. His under-feathers having been thoroughly soaked, he rushes back to his distant nest with speed sufficient to admit of his arriving before the moisture has evaporated. As he alights the young ones thrust their beaks among his feathers, and suck every drop of moisture from them. There are more ways and means of gaining a livelihood and maintaining a species in birdland than are yet included in the most complete of our works on natural history.

SOME OF THE INNER SENSES

Our Debt to Common Sensibility, the Organic Sense of Well-Being, the Muscular Sense, and Equilibration

MISERIES OF INTERNAL ORIGIN

IN the last three chapters of this section we have discussed the so-called "five senses" which are the "gateways of knowledge" from the outer world to ourselves. So far as positive science goes at the present time, the list of such senses is exhausted in what we have discussed. But before we proceed to a set of senses which are markedly different in kind, since the stimuli which arouse them are not derived from the outer world at all, we are bound to make formal admission of the possibility that there may be other senses, common to all mankind, or perhaps only exhibited appreciably in a few exceptional persons, which acquaint us with external things in ways which sight, hearing, the cutaneous senses, smell and taste, do not cover at all. Questions are here raised to which we must endeavour to return as adequately as may be, in the uncertain and highly disputed condition of the available evidence. But here we note that our foregoing discussion of the senses which connect the brain with the outer world must not be regarded as excluding the possibility of such senses as might be called a "sixth sense" of direction, a "telepathic sense" by which its possessor might sense, feel, or perceive, as if whispered, the thoughts of another person, a "magnetic sense," a sense of the presence of water under the surface, as in the described cases of certain water-finders, and yet other senses as to which the evidence and our present ideas are still more dubious.

At this present stage of our discussion, the existence of any of these senses or of any others, hereafter to be described by anybody, is neither asserted nor denied. This attitude may be disappointing and unsatisfactory; the reader might prefer a flat denial of what is not proved, after the too confident and arrogant fashion of most men of science in the last third of the nineteenth century, or he might prefer a generous acceptance of the many assertions which have been made as to the telepathic sense, the sense of water, and so forth. But the attitude of true science, at this stage of our inquiry, is that of scepticism, which literally and properly means not denial, as some suppose, but a *continuous looking about*, in the absence of final knowledge.

Meanwhile our duty is to proceed to the present end of our positive knowledge; and the first fact we discover is that, whatever may hereafter prove to be the truth regarding any supposed "sixth sense," not only are the five "senses" many more than five, but also there are quite a number of "sixth senses" to be found within the domain of the body, if we look for them properly. The most satisfactory way in which to define and distinguish these senses is to call them the inner senses, as distinguished from those outer senses, as they may be called, which we have already discussed. The feature which those outer senses have in common is that they are all concerned with the reception and interpretation of stimuli proceeding from without. But the domain of man, or the City of Mansoul, as Bunyan called it in his "Holy War," requires not only gateways of knowledge from without, but also means by which knowledge as to what happens within it can be brought to the notice of its central ruler; and no sooner do we look into this subject than we find that the life of man could not be successfully maintained for a single day were it not for those inner senses of which very few of us have ever heard or thought, yet which are indispensable to our lives, as even sight and hearing are not.

No doubt these inner senses are to be ranked on a humbler plane than sight and hearing, or even than the senses which have their seat in the skin, the tongue, and the

nose; but all those other senses are to be regarded as later, if higher, developments, the evolution and use of which are only rendered possible by the prior and continued existence of the inner senses, without which the body could never have been built at all, and could not be maintained for a day. The finest telescope in the world would be useless if the observatory from which it looked forth was only chaos within.

The Organisation of Man's Body Only Possible Through the Service of Inner Senses

We have to learn, then, that the internal organisation of the body, by means of which the City of Mansoul is able to exist as a unity, despite its inconceivable complexity of structure and function, is only made possible by the service of the inner senses, some of which, though not all, must now be discussed. We cannot discuss them all, for the excellent reason that, as we just begin to realise, there is no end to them. When digestive juices pour into the stomach after food has entered it, something somewhere has *felt*, and has given orders accordingly; and that is merely one instance of an indefinite number, to which any of us can contribute units if we will. But here we shall only discuss a few of the inner senses, which are more general and more constant in their action, and to which definite names have been given by the students of physiological psychology.

As we have already seen, sensibility—or irritability, as it used to be called—must be regarded as a universal attribute of protoplasm, or living matter; and our senses, even including vision and hearing, must be regarded as evolutionary developments from a primitive sensibility which is possessed by every living part of every living creature, and therefore by, for instance, our own blood-cells and gland-cells and muscle-cells, and all the other cells of our bodies.

The General Sense of Being Either Out of Sorts or "Fit"

This sense cannot conveniently be called "common sense," but may best be called common sensibility; and we must realise that every living part of our bodies—every part except the enamel of the teeth, the extruded parts, of nails and hairs, and so on —is endowed with this primal sensibility, and that, in many cases, there are nerves which run to the central nervous system and convey this common sensibility, or something corresponding to it, up to the brain itself. When we are in ordinary health, we are very little aware of these vague, faint, yet "massive" sensations which reach the brain from practically all parts of the body at once. When we are feeling "out of sorts," or bored, or tired, or when we are just sickening with influenza, or when something is wrong with the body as a whole, perhaps only because of absorption of poisons from a sluggish bowel, this common sensibility is affected, and it is largely because this common sensibility is affected that "we" feel not quite ourselves, as we say.

On the other hand, the convalescent, or the town-dweller, breathing the air of the seaside or the mountain breezes, or even he whose physiological processes have been improved by a cheering letter, has largely to thank the altered condition of his common sensibility for his different impression of the world and life in general; it is really a different impression of, or from, his own body that he is receiving. It is very probable that the sense of "fatigue," and the sense of freshness after sleep, mainly depend upon the quality of the "common sensibility" which pours in upon the brain from the whole body, in different fashion according to the condition of our cells at large when they are bathed in fluids that contain waste products, or are perfectly fresh and free from all poisons.

Organic Sensations that Come from the Principal Internal Organs of the Body

A very slightly higher development of common sensibility is what is called "organic sensation," or the "organic sensations," those which proceed, with a little more definiteness than common sensibility, from the various organs of the body, and notably from the alimentary canal and the heart. These organic sensations are often described as if they were only of importance when our attention is directed to them on account of their unusual character. Thus they play the chief rôle in the celebrated theory of the nature of the emotions which was popularised by the late Professor William James, and which we shall have to discuss fully at a later stage. But the wide discussion of that theory has led many psychologists and others to suppose that the organic sensations are only important when, for instance, we are conscious of the palpitation of the heart under the influence of, or in association with, the emotion which we call fear, or that which we miscall "love." There is no doubt that these organic sensations are very important at such times; and no one will question the great part which is played in our lives by such examples of organic sensations as hunger

and thirst, nausea, colic, flushing, palpitation, impending suffocation, or breathlessness, and so on. But the first and most important fact which we have to learn about common sensibility and the organic sensations, considered together, and especially in reference to the latter, is that these sensations furnish a sort of permanent background or substratum or pervading element in consciousness, an element which may be very vague and indistinguishable, and the very existence of which we may incline to deny until we have studied the subject, yet one which subtly plays a part of the first importance in our psychical life.

How the Organic Sense of Well-Being Underlies All Possibility of Happiness

It is especially the students of the mind diseased who have contributed to our knowledge of this subject. They have shown that our organic sensations, when they are as they should be, contribute to, or rather constitute, what may be called an "organic sense of well-being," which may sound a matter of small moment when first we hear of it, but which underlies all possibility of happiness. Everything outside us may be smiling and attractive, our pocket full of money, nothing irksome to do, no boredom to fear, but if our organic sense of well-being fails us, and is become an organic sense of ill-being, we are the most miserable of creatures. "Life's but a walking shadow," and happiness the mania of fools. This is the underlying psychological basis of melancholia, that great group of insane states in which the common and essential element is misery *of internal origin*.

What may be the cause of the perversion of the organic sensations in any particular case does not here concern us, but we are concerned to realise, once and for all, what part the perversion of this element of consciousness can play, and therefore what a part its right behaviour plays, in our normal condition of happiness.

The Misery of the Person who has an Organic Sense of Ill-Being

Faced with a case of melancholia, or even with the organic depression or mere melancholy not positively insane, which we often meet around us, the tyro who only believes in the "five senses" is apt to think that the cure must be effected in terms of them—change of scene, cheerful surroundings, bright or soothing music, absence of noises, French cooking, and so forth. He soon discovers that his patients may change the skies above them, but not the hearts that roam, as the poet says. The unpleasant sensations which produce the patient's sadness do not arise from without, and cannot be removed, at any rate directly, by changing what is without. They arise from within. And while the tyro wastes his time on change of scene and company and so forth, the expert seeks to correct the morbid chemistry, the fatigue, the influenza poisoning, the physiological exhaustion from too frequent child-bearing or too long continued nursing, which has perverted the organic sensations of the body, so that the unfortunate person's consciousness has a permanent and all-pervading element which is an organic sense of ill-being, and turns every external source of happiness or peace or nourishment into Dead Sea fruit.

Some day, when the facts of modern science are made popular enough to invade even the curricula of our theological colleges, and our seminaries for teachers, it will be seen that these facts, which are so familiar to students of insanity, and so unfamiliar to everyone else, furnish the basis for a new-old philosophy of life. The old doctrine that the source of happiness is to be found within is seen with redoubled force when we realise that it is true not only in the purely spiritual or psychical sense, but also in the sense of our foregoing argument, which is at least as bodily as it is psychical

The Internal Causation of Unhappiness too Little Studied and Understood

An infinitude of misdirected labour, of superfluous pity, of superfluous envy, of contempt at discontent, and of admiration at content in hard circumstances would required to be reconsidered if we were all acquainted with these simple and indisputable and profound and universally illustrated, yet almost unknown, facts of our bodily-mental organisation. Notably would the spread of popular science—or popular knowledge, which means the same thing—in this respect enable us, all over the land, to avert incipient melancholia, by understanding it, and dealing with it accordingly in terms of its *internal* causation. But at present the public knows nothing of this subject, the bulk of the medical profession knows little more; and it is the experience of every expert in insanity that the warning signs of approaching melancholia are ignored, and the causes which produce it are maintained or increased, in an appalling number of cases, even by those who care most for the person in question, and would do anything to avert the calamity, if they knew. Meanwhile, with such preventable catastrophes

on every hand, a writer can only try to state the facts as clearly and forcibly and responsibly as possible, insisting not merely upon their scientific and philosophic interest, which is of the first order, considering that happiness is "our being's end and aim," which we all pursue, though it is within us or nowhere, but insisting also upon the high practical importance of this discovery in relation to the prevention of a very common and awful and probably increasing form of insanity which is constantly responsible for an appalling number of tragedies, especially those which culminate in suicide.

Different Types of Optimism and of Pessimism Physiologically Considered

This is one of the foremost subjects for discussion in any modern treatment of the subject of personal hygiene, and especially the hygiene of the mind, which far transcends in importance the hygiene of the body; and it can only properly be dealt with on the basis of the knowledge regarding organic sensations which recent work in physiological psychology has placed at our disposal.

"Feeling seedy" after a debauch, "run down" after a strain, looking on the world with a "jaundiced eye," even the very word "melancholy," which means "black bile"—all such states and expressions as these, together with their opposites, such as the successful lover's feeling of "walking on air," find their clue and content in what we learn of the "organic sense of well-being." Similarly, we begin to see that there are many types both of optimism and pessimism, and that there is a world of moral difference between the *emotional optimism* of, say, the revival convert, the *organic optimism* of the man who has just dined, and the *rational optimism* of the philosopher or the poet who believes that "there shall never be one lost good." But that is too wide a subject to trench upon now, though it is worth mentioning in order to show how far we may be led by the aid of this clue which modern psychology places at our service.

The Movement-Feeling which Co-Ordinates Muscular Action Considered as One of the Senses

Not far removed from common sensibility and the organic sensations are what psychologists now call the "kinæsthetic sensations." The word is unfamiliar, but readily suggests its meaning, which is "movement-feeling." Kinæsthesia, or kinæsthetic sensation, is our feeling of the movements and of the consequent position of the various parts of the body, and especially of the limbs. This sensation may well be expected to depend upon the muscles, which are the motor-organs, and it indeed does so to such an extent that until recently we used to speak of it as the "muscular sense"—the sense which has its seat, and indeed its end-organs, in the muscles. And the experiments made by disease have long ago demonstrated to neurologists that this "muscular sense" is indispensable for our successful management of our bodies, and especially of our limbs.

But further inquiry has shown that it is more accurate to include the "muscular sense" in a wider term, for the very good reason that the muscles are not the sole end-organs of this sense, though their importance is first. We must include the tendons of the muscles, and the lining or synovial membrane, as it is called, of the joints. It is probable, also, that we should include a certain amount of sensibility in the skin, according as it is more or less stretched or relaxed or folded in the course of the movements which go on under it. The sum and meaning of the sensory impressions derived in these ways is that we know where we are and what we are doing. Otherwise such a feat as putting food into our mouth with the eyes closed would be quite impossible.

The Spontaneous Regulation of Muscular Action by which We Write or Sew

That part of kinæsthesia which is derived from the muscles and tendons serves to tell us of the degree of force with which the muscles in question are being put into action; and apart even from the fact that this helps us to know where the muscles and limbs they belong to actually are in space, it means also that we are able to regulate as we please the degree of force which we find desirable to use for our purpose. Without the muscular sense no one could play the piano or billiards or cricket, or even write or sew. No doubt the reader is bound in large measure to take such statements as these on trust, but he would have only too little need to do so if he could observe those unfortunate victims of nervous disorder in whom the kinæsthetic sense is impaired or lost.

When we trace upwards to the brain those nerve-tracts in the spinal cord which serve the kinæsthetic sense, we find that they mostly go to that large and well-marked area of the cerebral cortex which we already know under the name of the psycho-motor area. It is evidently a matter

of convenience and economy that the centre for kinæsthesia, which is mainly composed of the muscular sense, should be intermingled with the centre which controls and orders the movements of the muscles. But it is particularly to be noted that several strands of nerves which belong to kinæsthesia do *not* travel to the cortex or to the cerebrum at all. They branch off at lower levels and run to the cerebellum.

The Apparatus in the Ear that Preserves Our Equilibration

The full meaning of this notable fact can only be revealed, however, when we study the last and, in many ways, the most remarkable of what we have called the inner senses, for this study will show us an admirable and subtle co-ordination between the kinæsthetic sense and another sense, quite distinct in situation and mechanism, which yet plays a complementary part to that of the kinæsthetic sense in the activities of the body. This last of all the senses of man, so far as we have positive knowledge of them, is known as the sense of equilibration, and it is the sense by which a man literally "keeps his head" in the turmoil of the world.

In our study of the organ of hearing, with the amazing structures which comprise what is called the inner ear, we encountered, within the hardest part of the temporal bone on each side of the head, a trio of semi-circular canals, filled with fluid, and placed at the vestibule, as it is called, of the inner ear itself. This apparatus looks like an adjunct of the organ of hearing, and has been historically evolved *pari passu*, or in equal steps, with it. But when we examine its functions we find that we are wrong in crediting it with the special function of locating the direction of sound. Though its structure would seem exactly fitted for that purpose, in point of fact the vestibular apparatus, as it is often called, has nothing whatever to do with hearing.

An Illustration of the Association of Nerves to Promote Community of Function

True, it is at the vestibule, or, rather, it forms the vestibule, of the inner ear; true, also, its nervous supply joins that of the ear and forms part of the so-called auditory nerve.

But careful microscopic study of this nerve and its connections shows that, though we simply speak of the eighth or auditory pair of cranial nerves, we should be wiser to speak of two pairs, which might be called 8A and 8B. One of them is indeed auditory. But the other, though bound up with the auditory nerve for a part of its course, is totally distinct in origin, function, and destination. It is usually called the vestibular part of the auditory nerve, but the shorter as well as more accurate name for it is simply the vestibular nerve. This pair of nerves, one on each side of the brain, should undoubtedly be ranked as one of the pairs of cranial nerves, and might be called 8B, as is here suggested. Its end-organ is the trio of semi-circular canals on each side of the head; and when we trace it inwards towards the brain we find that its fibres part from those of the auditory nerve proper, with which it has travelled part of the way for convenience, and pass to the cerebellum, instead of to the cerebrum, where the centre of hearing is, of course, to be found. Lastly, we note that the fibres of this vestibular nerve actually become all but interwoven with the fibres already described, that come from the kinæsthetic path in the spinal cord, and that pass to the cerebellum instead of the cerebrum, like most of their fellows.

The Semi-Circular Canals of the Ear, and Their Relation to the Kinæsthetic Sense

Here, then, is a perfect anatomical demonstration of some community and complementariness of function between the kinæsthetic sense, which tells us where our limbs are, and the sense, whatever it be, of which the end-organs are the semi-circular canals. If the semi-circular canals from both sides be considered together, we see that, as the diagram readily shows, they form three pairs, arranged like the three dimensions of a cube, so that they exactly correspond to the "three dimensions of space." Whatever movements the head makes, or whatever movements it is made to make, as on board ship in bad weather, some pair or pairs of these canals will be affected. The fluid with which they are filled must tend to move. If a ship dips only, then only the vertical pair of canals (one on each side of the head) will be affected; if the ship rolls only, then only one pair of horizontal canals will be affected; but if she dips and rolls, and rises and falls, it will not be long before all six canals find stimuli affecting them, and the amateur sailor will very likely be sea-sick. If he had left his semi-circular canals at home—he may now incline to think—he could have strode the deck and puffed his black cheroot with the best sailor aboard. But the case of sea-sickness does not mean that our semi-circular canals are superfluous, and only

there to annoy us. On the contrary, they serve for the head and the body, as a whole, just the functions which the kinæsthetic sense serves for the various parts of the body, and especially the limbs. It must be remembered that the head has only one movable joint—that of the lower jaw. (A pair of joints, of course.) The "muscular sense" has no end-organs, except the mere scalp, by which it could tell us where our heads are. Something more subtle is required, and these wonderful semi-circular canals are the solution of the problem.

The Tragic Confirmation by Disease of the Observations of Physiologists

The evidence regarding their function is now conclusive. A distinguished former teacher of the present writer, Professor Crum Brown, of Edinburgh, made a series of conclusive and amusing observations upon himself and others by means of revolving tables upon which the subject stood, while they were rotated in alternate directions at graduated speed. He clearly showed how one's sensations in such circumstances exactly corresponded to the structure and arrangement of the six canals.

This is a striking instance of the value of having a *pair* of organs. It is decidedly advantageous to have a pair of eyes and a pair of ears, but a single eye or ear is very nearly efficient. On the other hand, the doubleness of the vestibular apparatus is essential for its function, which is to register every movement and every possible combination and direction of movement of the head. The tragic experiments of disease precisely confirm the evidence of anatomy and the observations already mentioned. In disease of the vestibular apparatus, the characteristic symptom is an almost constant and uncontrollable vertigo; and it has been found that where only one or two, but not all, of the three canals on either side have been damaged or thrown out of action by nervous impairment, the patient's vertigo is limited to movements in the particular direction or directions of space which corresponds to the canal or canals affected. This fact recalls our illustration from the case of sea-sickness.

The Correspondence of the Three Canals to the Three Dimensions of Space

The details of structure of the vestibular apparatus are of comparatively small importance. The one essential fact as to the local machinery is that the three canals are arranged to correspond to the dimensions of space. For the rest, we need only note that the canals contain a number of special cells provided with hairs which project into the fluid which fills the interior of each canal. The column of fluid is so slender, owing to the tiny calibre of the canals, that we cannot suppose the fluid to be actually oscillated by movements of the head, as Professor Crum Brown originally suggested; but such movements will cause alterations of pressure in the fluid which must have just the same effect upon the hairs which are bathed in it as actual to-and-fro movement of the fluid as a whole would have. The reader who wishes to experiment upon himself in a less agonising fashion than is involved in a bad sea-voyage need only exercise a little ingenuity for the purpose. The familiar fact that rotation in one direction makes one giddy, and that the giddiness can be most quickly annulled by corresponding rotation in the other direction, illustrates the exquisite fashion in which the three pairs of canals are adjusted, and in which they are fitted to appreciate every movement of the head, and to protest against whatever is unusual, and therefore possibly dangerous.

The Inner Senses the Observant Protectors of Man

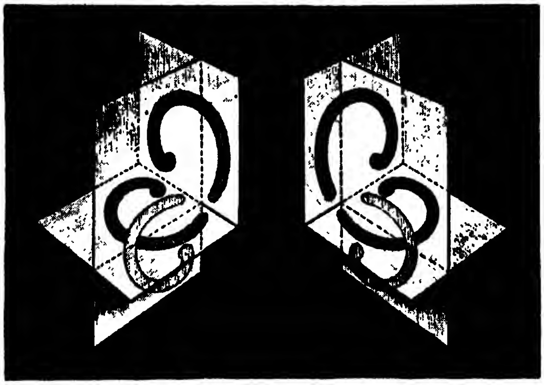
And if the reader is inclined to argue, as many students of the inner senses have done before him, that these senses are much exaggerated by scientific report, and that one really does not feel what one is alleged to feel, the answer is that these senses, which are protective rather than instructive—in even greater degree than touch, pain, and smell—do not arouse the attention of consciousness except when there is anything wrong.

They leave us alone to live our higher lives so long as all is well, but they are on the look-out all the time, though our conscious selves do not trouble to perceive what they perceive. Though we largely owe our happiness to our organic sensations, we do not thank them when all is well, and we are indignant with them when anything goes wrong, and we feel squeamish, or "hipped," or "off colour," though they are only doing their thankless duty.

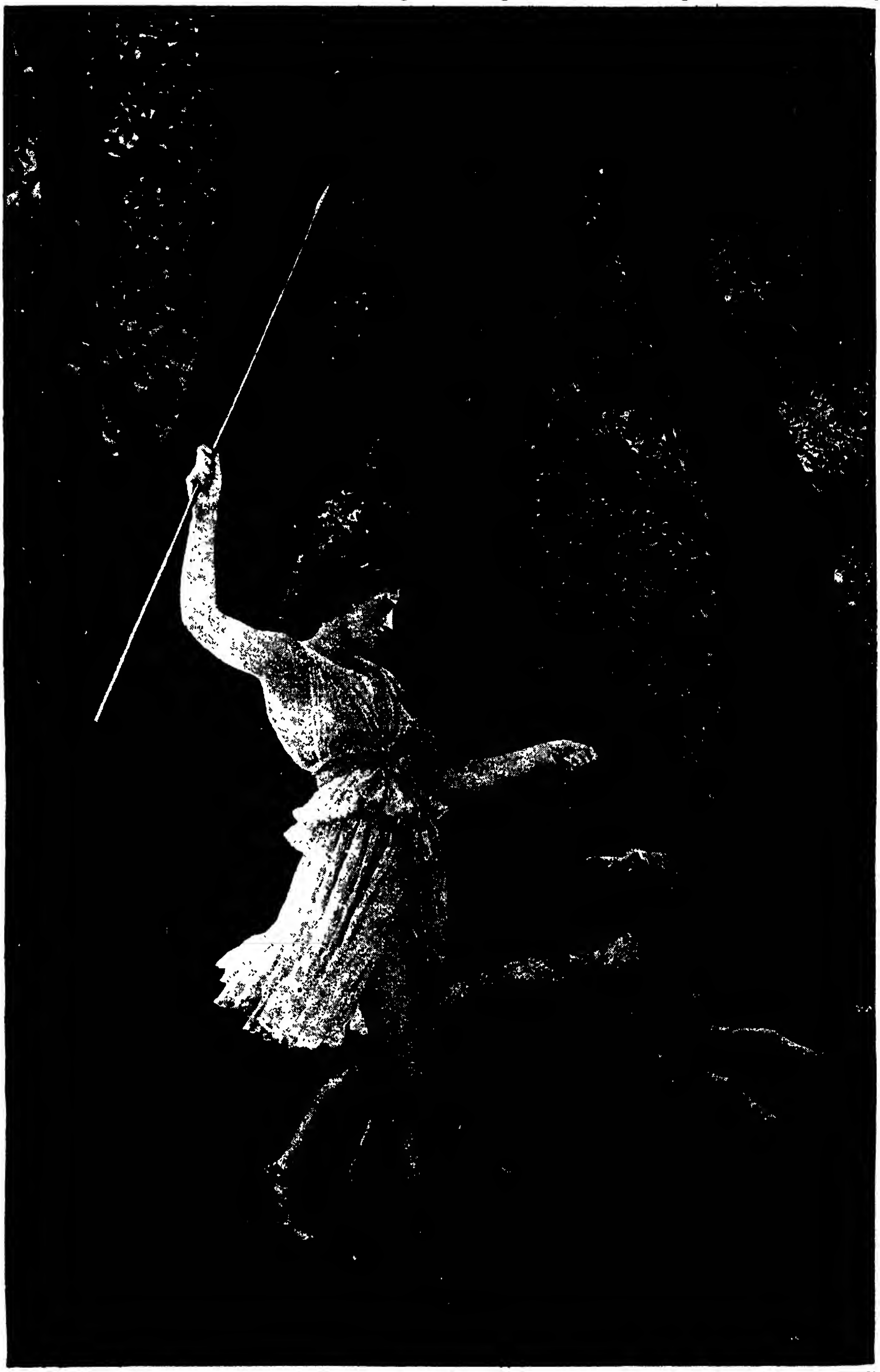
Similarly, we may be inclined to deny the importance or the existence of our sense of equilibration, or the vestibular sense, as it is sometimes called, so long as all goes well. But the seasick tourist or air-sick aviator, or novice in a ballroom, or victim of vestibular disease, is very well aware that the sensation of giddiness is exceedingly real, even though he cannot point to the sense-organ whence it arises, as he can

point to his eye as the sense-organ of vision; and on consideration he will see that there must be a *sense of not-giddiness, too.* Here is a " sixth "—or should it be sixteenth ?—sense which everyone possesses, and which no one can possibly do without; but the sense-organs, instead of being placed in relation to the outer world, like those of the outer senses, are buried deep in the hardest bone in the body, and have no channels of conduction from the surface, as has the inner ear, which lies so misleadingly close beside them.

No further comment need be made upon the anatomical fact that many fibres from the kinæsthetic tract of the spinal cord run to the cerebellum and join the fibres of the vestibular nerve there. We now see the meaning of this arrangement. Obviously, the kinæsthetic and vestibular senses work in harmony. The child that learns to walk, Blondin crossing Niagara on a tight-rope, the sure-footed and comfortable sailor, the trick cyclist—all these and a thousand more are instances of the education of these two senses. In dancing and in various forms of acrobatics they are still further developed, but they reach their highest possibilities in skating. If we are to arrange and classify "arts" in terms of the senses, a method which has its uses, then clearly the " art of skating " is the analogue, for the sense of equilibration, to the art of music for the sense of hearing, or the "gastronomic art" for the senses of taste and smell. But here, again, we must apply our criterion of the internal connections of the particular sense which we are cultivating; and the champion figure-skater or cook will be measured against the great musician or painter, according to the fact that the sense of equilibration leads to nothing more than equilibration and the consequent protection of the body, and has its centre only in the cerebellum, while vision and hearing lead to instruction and revelation for the highest part of the psyche of man, which resides in the cortex of the cerebrum.


THE PLANES OF THE CANALS WHICH ACT AS THE BALANCE CHAMBERS OF MAN THE ERECT

One point remains, though indeed it is no point, but the root of a philosophical treatise, only parts of which have yet been written. We have included the sense of equilibration among the inner senses, and such it is; but evidently it gives us information about the external world, in that it tells us where we are in relation to the external world. Are we not, on reflection, bound to say that this sense of equilibration is really nothing less than our sense of space? Philosophy and mathematics argue as to the tri-dimensional character of space, and they can construct new geometries, super-Euclidean, on the assumption of a fourth dimension, which to length, breadth, and depth adds an unthinkable "inwardness." Nor need they stop at four dimensions, for the geometry of space of any number of dimensions—*n*-dimensional space, as it is called—has been deeply explored of recent years. Observe that mathematics, including geometry, is pre-eminently the *exact* science, where proof and logic are rigid, and where casual or haphazard or superstitious thinking are instantly detected and condemned. But here we find mathematics constructing and proving to demonstration, and finding practically useful, a geometry which assumes that space has more than three dimensions. Obviously this leads the way to strange speculations, and opens the door to many possibilities, not least of all for the psychical science of the future. And here a question arises which has to be answered. The immediate relation between our conception of space and the number of the canals is indisputable, and requires explanation. It cannot simply be asserted as a coincidence; and philosophy must attempt to answer the question as to which is causally first—the number of the canals, giving rise to our tri-dimensional conception of space, or space actually tri-dimensional, and so causing the evolution of a trio of canals. The writer's own position is that he still inclines to the latter view, but with much less confidence than when he first studied the subject.



DIANA, THE PATRONESS OF THE HEALTHY LIFE—FROM THE PAINTING BY HENRY HOLIDAY

THE EFFECTS OF ALCOHOL

An Outline of the Evidence that Alcohol Does Not Keep Out, but Lets In, the Body's Enemies

THE STORY OF AN UNHOLY ALLIANCE

We must now try to compress within a reasonably brief compass the results of the many investigations that have now been made by exact methods into the actions of alcohol upon the body in health and disease. These investigations have resulted in a formidable body of knowledge, only the main outlines of which are dealt with, even in the well-known and standard volume on the subject, "Alcohol and the Human Body," by Sir Victor Horsley and Dr. Mary Sturge, of which a cheap but complete and revised shilling edition has lately been published by Messrs. Macmillan. Here we shall deal with the subject in our own way, and shall attempt to define the measure of our knowledge as recently as the last International Congress on Alcoholism, held at The Hague late in 1911, the report of which Congress is not yet in the hands of the public.

Like chloroform, ether, and a large number of allied substances, alcohol must be numbered among what are called the "protoplasmic poisons," the action of which is essentially toxic to all forms of protoplasm, or living matter. Even the yeast-plant is soon killed by the alcohol it produces, if that be allowed to accumulate. The action of alcohol upon green plants also can be definitely classed as toxic; and when we pass to the animal world the results are the same. Alcohol acts as an antiseptic, by its action upon the microbes of putrefaction, and it thus ranks high as a preservative of all forms of corpses; but for the living body, upon whose cells it acts as upon the living cells we call microbes, its preservative action is naturally reversed. If we begin with the simplest animal cell, such as the amœba, this destructive action of alcohol, beginning with paralysis (perhaps after a brief stage of what simulates stimulation), is clearly shown. From this humblest we may pass to the highest form of animal life—that of our own bodies; and this extreme transition will be justified when we remember the astonishing resemblance between the free-swimming white cells of our own blood and the amœbæ of the ponds. In general, the reactions of these two types of cell are notably similar, and that is the case here.

The consequences are of the gravest. As we saw at the very beginning of our present study of health, the body maintains itself against its living enemies mainly and cardinally by means of its leucocytes, or white cells. In the presence of such foes as, say, the microbes of pneumonia or consumption, the number of leucocytes in the body increases; and, given the invasion, this multiplication of the leucocytes, which is known as leucocytosis, is a good omen for the patient, for though we call it a "symptom" of the disease it is really a demonstration of health, and the best promise for its return. Some thirty years ago Professor Metchnikoff found, first by study of a minute creature called the water-flea, that these leucocytes attack and destroy microbes and other invaders of the body. More recently he has proved, at the Pasteur Institute—and his results have been repeatedly confirmed and amplified since—that alcohol, present in the blood even in surprisingly small quantities, paralyses the leucocytes, so that they cannot do their work so well. This has been noticed with other intoxicated garrisons, long before the microscope was discovered. Yet, until very recently, almost every case of, for instance, pneumonia was regularly treated with large doses of spirits, with the idea of stimulating the patient's heart and powers of resistance.

A dozen years ago, when the writer was responsible for patients in two wards of the

Royal Infirmary of Edinburgh, one of the most famous hospitals in the world, the routine practice was to administer alcohol in such cases. But it has lately been reported that Sir Thomas Fraser, Professor of Therapeutics in the University of Edinburgh, who regularly gave alcohol in those days, has for some two or three years past given no alcohol to any of his patients. That fact is typical of the change which a decade has wrought, mainly because of the evidence first adduced by Metchnikoff in Paris. In all the great hospitals in this country the same change has now occurred. The Royal Infirmary of Edinburgh now spends sixpences upon alcohol annually, where it used to spend thousands of pounds, and the same has been shown for the great hospitals in London. While the alcohol bill has fallen with a rush, the milk bill has steadily risen, and results steadily improve, both as regards the death-rate and the length of convalescence. This applies not merely to such "medical" diseases as pneumonia, but also to "surgical" diseases. As we have seen, in both alike the essential fact is the same—the fight between the body, and especially its white cells, on the one hand, and invading parasites on the other.

The Proof from Pneumonia Statistics that Alcohol is Detrimental

In a scientific work it is necessary to appeal to evidence, and here we may briefly note two lines which have led the foremost members of the medical profession to their present practice. In one instance, since confirmed, and controverted by no member of the old school, pneumonia patients or their relatives were given their choice as to whether they should have alcohol or not. Every condition was made identical, in the two sets of patients thus chosen, except on this one score. Over a long period, and with a large number of cases, it has been found that the death-rate is about 15 per cent. higher in the patients who are "treated" with alcohol than in those who get none. In other words, of every hundred patients suffering from pneumonia, who are treated with alcohol in what, until now, has been the ordinary way, about fifteen are killed by it. Interesting questions of responsibility clearly arise when we come to estimate and appraise the usefulness of those practitioners who still adhere to nineteenth century practice in this respect; and, meanwhile, it behoves the intelligent public to acquaint itself with the practice of the best hospital physicians, whose recent results are without parallel in the past. No cure for pneumonia patients has yet been found, but even to stop killing them is progress.

The second line of evidence had best be quoted in the words of our great master, Professor Metchnikoff himself, who first showed that the leucocytes are, as he calls them, phagocytes, or "eating cells." The following sentences are translated from his memorable lectures delivered before the Royal Institute of Public Health in London, in 1906, since when they have been much more than confirmed.

Metchnikoff's Testimony that Alcohol Lessens Power of Resistance Against Disease

"Although the phagocytes belong to the most resistant elements of our body, yet it is not safe to count on their insensibility towards poisons. We have seen how they are harmed even by small doses of opium. I am not able to enter into details with regard to all the substances which are adverse to phagocytic action, but I must call your attention to the influence of alcohol on immunity. It is well known that persons who indulge too freely in alcohol show far less resistance to infectious diseases, especially to croupous pneumonia, than abstemious individuals. The vaccinations against hydrophobia carried out on persons bitten by mad animals are almost always successful, but those cases in which the treatment does not stop the outbreak of the disease are most frequently observed in individuals addicted to alcoholism."

Then, following a technical account of a long series of studies, Professor Metchnikoff stated the following conclusions.

Metchnikoff's Conclusion—A Harmful Action on the Nervous System and the Blood

"As has been established by Massart and Bordet, leucocytes are susceptible even to small doses of ethyl alcohol, and exhibit paralysis of sensation in the presence of this substance. Besides its deleterious action on the nervous system and other important parts of our body, alcohol, therefore, has a harmful action on the phagocytes, the agents of natural defence against infective microbes. . . . As a logical consequence of the experiments on the weakening of immunity under the influence of alcohol, it has been suggested that we must eschew this substance in the treatment of infectious diseases . . . We must strongly insist on the danger of alcoholism with regard to resistance against disease-producing microbes."

Having publicly stated, as recently as eight years ago, that alcohol retains its

utility in fever, though discredited in many other respects, the present writer is grateful for the opportunity to undo, as far as possible, any ill consequences of teaching which he now knows to be erroneous. In this and several other respects the attempt to say impartially whatever was supposed to be known in favour of alcohol has proved to be a waste of good intention. The special argument in favour of alcohol in fever was that which was accepted by Sir Thomas Fraser, one of the foremost living students of drugs, and taught by him to the present writer, as to many others; and it is an argument which, as we have seen, its distinguished advocate has now abandoned definitely and unreservedly in his own practice.

It was that the body requires food in fever; that the process of digestion is difficult or even impossible in this condition of the blood, and that therefore we should give alcohol, which was believed to be a food, with the special virtue that it requires no digestion whatever, but can be absorbed as it is into the blood and from the blood by the tissues. So long as the major assumption was granted, this seemed sound argument; but, as we have seen, in the great hospitals alcohol has nevertheless been abandoned and replaced by milk (which can easily be predigested outside the body), even in fever.

The Reason Why the Writer of These Articles Makes a Recantation

The reason is that the supposed food-value of alcohol has not been upheld by subsequent research. The drug is in part destroyed, but that, as we have seen, proves nothing. Careful experiment upon the heart, the condition of which is so important in all acute fevers, has shown that alcohol does *not* support its action, though sugar does. In fact, nothing is more notable in recent chemical physiology than the steadily increasing evidence in favour of sugar before decomposition, and against the characteristic product of that decomposition. As we already know enough to see, every food substance must either supply a necessary ingredient of the bodily composition, or it must be a source of energy, or it must somehow expedite necessary bodily processes. As regards the first of these possibilities, no one claims anything for alcohol. It may be found in minute traces in the abstainer's body, but only as an effete product. Nothing alive, other than the vinegar bacillus, tries to live upon it, except man. It does not occur in milk, except in that of the drinking human mother. It contains no nitrogen, and is thus incapable of forming a part of any living tissue. But, though it thus has no claims to rank with the proteins, it might supply energy, and thus be what is called a "protein-sparer," preventing the body from having actually to burn its proteins, in the absence of any cheaper fuel—as a householder might have to burn his piano and floors in the absence of coal and logs. But the evidence now available strongly suggests that alcohol cannot rank as a food of this class, for it does not reinforce the energies of muscular tissue, as the experimental study of alcohol and other substances perfused through isolated and surviving hearts, removed from animals first killed, has shown.

Alcohol Not a Source of Energy Because It Lowers the Temperature

Most notably, the claims of alcohol as a source of energy, whether muscular energy or heat energy, have to face the fact that this substance lowers the temperature of the body, instead of raising it, as is ingenuously supposed by those who "take a nip to keep out the cold." The fact is that this drug is a "protein-sparer" because it interferes with the nutritive processes which involve the use of the protein and the fuel-foods. It is a general property of alcohol that it retards fermentation. This is doubtless the key to its action on living matter, since life, physically considered, is a series of fermentations. Now, the processes by which the body utilises its food are all fermentative, and alcohol interferes with them at their very beginning by its action on those initial processes of fermentation by which the red cells of the blood give up to the tissues the oxygen they have gained from the lungs.

The Direct Interference by Alcohol with the Internal Process of Combustion

This action of alcohol upon the red cells of the blood is probably only one degree less important than its action on the white cells. The business of the hæmoglobin which gives the red cells their colour is to form a loose compound with the oxygen it meets in the lungs, and this compound, known as oxy-hæmoglobin, is decomposed by ferment action, wherever the tissues need it. But alcohol, like certain other substances, has the property of interfering with this sequence of events, so that the oxy-hæmoglobin is not readily decomposed, and thus the tissues are "starved in the midst of plenty" of oxygen. Hence, one

reason why alcohol lowers the temperature of the body—by its direct interference with the combustion whence the body derives its heat. Hence also we find that the habitual consumption of much alcohol, in cases where the stomach of the drinker is resistant and alcoholic dyspepsia does not supervene,. usually leads to the accumulation of superfluous, unoxidised tissue in the body, and the drinker becomes obese. Certain alcoholic beverages, such as beer, contain small but definite amounts of food material, which, if properly burnt up, would provide the body with heat and energy, but the alcohol which is taken with them interferes with their combustion, and consequently they accumulate.

The New View of the Action of Fever on the Body

The diminished production of heat may be of still further importance. We know definitely that the maintenance of the normal temperature of the body enables it to resist the attacks of microbes. We know also that when microbes have taken their hold upon the body it commonly raises its own temperature—with the production of what we call fever—for the purpose of aiding it in its resistance. Until the most recent times doctors have regarded fever as vicious in itself, and have opposed it by all manner of means, especially irrational ones, such as antifebrin, antipyrin, and other drugs which lowered the temperature by a directly poisonous action upon the vital efforts which were raising it. We know now that such methods were disastrous. Furthermore, it has been proved by crucial experiment and observation that the various degenerative changes in the body, which used to be ascribed to fever as recently as a decade ago, are not at all the results of the raised temperature of the body, but are toxic, the results of its poisoning.

Fever a Part of the Bodily Reaction Against Poisons

If the poisoning be present, but the temperature kept down, these disastrous changes still occur. If the temperature be artificially raised, as in a Turkish bath, or internally raised in hysteria, in the absence of microbic poisoning, and be maintained for long periods even at levels which sound incredible, these degenerations do not occur. And we are now certain that fever is part of the bodily reaction against poisons, and is valuable on many accounts—as, for instance, that poisons will be more quickly burnt up in a hotter body.

It follows that a second argument for alcohol in fever, which was maintained little more than a decade ago by such authorities as Sir Thomas Fraser and Sir Lauder Brunton, must be abandoned. They argued that alcohol was useful in lowering the temperature of fever. But now we see—and these distinguished authors see—that any substance which tends to interfere with the normal production of the bodily heat tends, therefore, to lessen its powers of resistance to microbes. Thus we find that the action of alcohol upon the red cells of the blood has, in effect, the same result as its action upon the white cells, which we have already studied. Not only does it directly paralyse the defenders, but it interferes with the conditions under which alone, if they be not paralysed, they can best do their work.

Further, it is notorious that alcohol dilates the superficial blood-vessels of the body—not merely those of the face only, but those of the body as a whole. Thus, throwing a large amount of blood to the surface, which is in contact with the cool external world, it markedly increases the loss of heat from the body. It thus strikes at the maintenance of the bodily temperature in two complementary ways—both by interference with the production of heat, and by acceleration of the loss of heat.

The Effect of Taking a Dose of Alcohol on a Cold Night

A dose of alcohol on a cold night, when one leaves a warm room, thus makes one feel warm, which we call keeping out the cold, but this is really letting out the heat. The nerves of temperature, which are situated in the skin, cannot distinguish between these two opposites, but the body pays its price. We fancy that if we feel warm we *are* warm, but our judgments are superficial, as are all judgments based on mere sensation without reflection. If the terminals of the nerves of temperature be bathed in a large quantity of rapidly flowing blood, for a time we feel warm, and the warmer the more rapidly we cool. We thus have a complete explanation of the fact that the absorption of alcohol, with subsequent exposure to cold, so frequently results in pneumonia, which is still by far the most fatal of all acute diseases. The microbe of pneumonia is quite commonly found in the mouths of healthy persons, waiting for a breach in the defences, a bout of intoxication on the part of the white garrison, or some other opportunity. The ingenuous amateur marches out into the night, fortified

by a dose of whisky in order to keep out the cold. His idea of keeping out the cold is to give out as much heat as possible to the cold, and to interfere, as far as may be, with the production of any more heat; and in order to do the thing in a thoroughly sporting way he arranges for the paralysis of his leucocytes. It would be a poor sort of *pneumococcus* that did not take such a chance.

The Significance Under Different Circumstances of a Decline in Temperature

We know that there are drugs—lamentably few—which lower a high temperature by striking at the cause which has incited the body to produce more heat. Quinine in malaria is such a drug. It kills the parasites that make the fever necessary, and with their death it declines. But to interfere with fever, while doing nothing to interfere with the activity of the microbes which have evoked it, is more akin to murder or to manslaughter than to medicine. Hence, the doctor of today who is abreast with the leaders of medical science welcomes the decline of his patient's fever if he believes that this indicates the disappearance of the need for the fever; but as long as the need persists—a need which alcohol does nothing to remove—he desires to see the fever well maintained, and nothing alarms him more than the failure of the body to maintain it in such circumstances. He knows that the falling line of the temperature chart may mean either the destruction of the invaders or the failure of the defences; and he will no longer be deceived into paralysing the defences with alcohol under the delusion that the decline in temperature thus caused indicates the destruction of the invaders.

The Diminution of the White Cells of the Blood in Alcohol Consumers

The relations between alcohol and the fluid part of the blood are still, as a whole, unknown; but, indeed, physiology cannot yet pretend to have any more than a superficial knowledge of the chemistry of the blood, in which lie many great secrets, still unlocked. But one important fact in regard to the white cells needs to be added. It is that, in those who regularly take considerable quantities of alcohol, the number of white cells in the blood is markedly diminished. The technical name for this diminution of the leucocytes, the opposite of the wonderful and beneficent "symptom" called leucocytosis, is leucopenia. We do not yet know how the chronic consumption of alcohol has this result, whether by increasing the death-rate of the leucocytes or by lowering their birth-rate in the blood-cell-forming tissues, such as the spleen, but our knowledge of the physiological effects of alcohol would suggest that it acts in both of these ways. But this remarkable discovery should involve far-reaching consequences if the teaching of Metchnikoff and modern science upon the functions of the white cells be correct. It leads us to expect that the mortality from microbic diseases in general, among the alcoholic part of any population, including even the regular moderate drinkers, will be definitely and constantly higher than among those who do not take alcohol.

And this, indeed, is the established fact, confirming Metchnikoff's teaching. The most dangerous trade we have is that concerned with the production and distribution of alcoholic liquors, as the Registrar-General's figures show. No one who knows anything of this subject, and has any charity in him, will revile the publicans, whose death-rate is so tragically high, or the grocers, whose own death-rate rose correspondingly when they were permitted to sell alcoholic liquors.

The Comparative Immunity of the Abstainer from Illness

Other statistical evidence is abundant, and constantly increasing—uniformly in the same direction. The medical profession has a heavy load at its door for the long-maintained but unholy alliance between medicine and alcohol.

Not very early in the nineteenth century a young abstainer who wished to insure his life was turned away from the doors of a great insurance company on account of the dangerous character of his habits. Today, the society which he then proceeded to found flourishes greatly; and its records and those of its rivals, in this country, the United States, and elsewhere, have clearly shown that the abstainer enjoys so high a degree of relative immunity from microbic diseases in especial that he lives, on the average, for several years longer than his fellows. The theory that this is, however, a pallid and worthless existence need only be countered by the further actuarial demonstration that, during his longer life, he suffers from several days' less illness annually on the average. The fact is, perhaps, worth mentioning at a time when the nation is setting out to prevent sickness, and pay benefits to the sick, and when the authorities declare that they will not pay

benefits to those whose conduct is such as is likely to retard their recovery.

Tuberculosis, the commonest and most deadly of all diseases, involves questions too large for discussion in this section, which deals only with personal hygiene; but the influence of alcohol upon the individual, in his personal relation to the tubercle bacillus, certainly concerns us here. Doctors long believed that alcohol was protective against consumption and tuberculosis in general. The "white plague," which makes so many pale faces, was supposed to yield to the properties of red wine, but now we know that nothing makes red blood like white milk, and act accordingly. Here are recent words by Dr. Sims Woodhead, Professor of Pathology in the University of Cambridge, on this subject.

Dr. Sims Woodhead on Alcohol as a Devitalising Agent

"Alcohol, far from being antagonistic to tuberculous disease, as was at one time supposed, is looked upon as one of the great predisposing factors in the production of both acute and chronic pulmonary tuberculosis; and it is generally accepted that in alcoholic patients tuberculosis is far more likely to assume an acute and generalised form than it is in the non-alcoholic patients; for, as Dr. Dickinson said: 'We may conclude, and that confidently, that alcohol promotes tubercle, not because it begets the bacilli, but because it impairs the tissues and makes them ready to yield to the attacks of the parasites.' In France, in the districts in which the greatest amounts of alcohol are consumed, the highest mortality from tuberculosis is met with, alcohol apparently acting as a devitalising agent, and rendering the person indulging in it to excess a more easy prey to infection. Baudron, in 1901, showed that the consumption of alcohol of 12·5 litres per person corresponded to a mortality from tuberculosis of 32·8 per 1000 living, whilst the consumption of 35·4 litres of alcohol per person corresponded to a death-rate from tuberculosis of 107·8 per 1000."

The Resolution of the International Congress on Tuberculosis that Alcoholism must be Fought

These conclusions have been extended and confirmed in later years. The International Congress on Tuberculosis, when it met in Paris, passed a unanimous resolution to the effect that the fight against tuberculosis must everywhere be combined with the fight against alcoholism. At the meeting in Rome in 1912 of this same Congress, which sums up the knowledge of mankind on this disease, a great quantity of additional evidence was forthcoming, not least from unfortunate Italy, where the rise of industrialism and the concentration in cities have given great opportunities to the allied forces of alcoholism and tuberculosis. It will be soon apparent to the public at large that these facts have large practical consequences. Already in this country, in France and in America, alcohol is practically banished altogether from consumption sanatoria, the scientific evidence against its use being now so overwhelming.

The general expectation that sanatoria are going to cure consumption on a large scale, and send the cured "back to their work after four months" or so, is not shared by the medical profession, as we shall see elsewhere in due course. But one thing is quite certain. It is that the public is going to receive an exact and liberal education in personal hygiene, in very large numbers, under the Insurance Act. Thousands of persons all over the country will learn in sanatoria, by daily precept and example, a host of hygienic truths which have already been or will be discussed in these pages; and one of them will be that if people want to avoid consumption, or recover from it, the less alcohol they take the better. Though it preserves corpses so well, it makes them also, and the living had better avoid it.

The Liability to Cancer Definitely Increased by Taking Alcohol

A very remarkable indication of the subtle action of alcohol upon the chemistry of the body has been furnished, within the last decade, from the study of cancer. This terrible and still imperfectly understood disease essentially consists of the development of "cannibal cells" from and in the cells of the body, in which an internecine and usually fatal war is then waged. Though these rebel cells act in all cardinal respects like parasites, cancer is almost certainly—quite certainly, we may indeed say—*not* due to a microbe or parasite of external origin at all. The relations of alcohol to this disease might therefore very well be wholly different from those which obtain in the case of the vast majority of all forms of disease. But careful study has shown that, other things being equal, the liability to the development of cancer is definitely increased by the consumption of alcohol. This fact, which has been known for some years, was stated with increased force and weight by the distinguished surgeon Sir Alfred Pearce Gould, in his recent

Bradshaw Lecture on Cancer, though it was denied by the defendant in a recent libel action. The complete interpretation of the evidence is impossible in the present state of our knowledge. At first sight it appears to mean that the customary presence of alcohol in the tissues—and we know that the regular drinker is constantly under its action, for a single dose is operative for more than thirty hours—leads to the change of type which occurs when normal cells become cancerous.

Self-Cured Cancer and Consumption More Frequent than We Realise

The present writer is strongly of opinion that that is not the true explanation, for many difficulties stand in the way of its acceptance—notably its failure to explain the *local* character of the disease. But, as Sir Alfred Pearce Gould and all other modern students of cancer are now demonstrating, that disease occurs, like consumption, far more frequently than we used to suppose, and probably by far the greater number of cases undergo a natural cure. The local development is due to local causes, acting how we cannot yet say, and then the question is whether the rest of the body will resist successfully or not. If it be successful, nothing more is heard—probably nothing was ever heard—of the disease. We know no more of it than most of us do of the fact than we carry healed tubercle in our lungs and elsewhere. The silent forces of the bodily resistance have simply done their work; and there is some reason to suppose, though this is very far from certain, that in cancer, as in other cases, the leucocytes do great service on behalf of the body.

However that may be, the teaching of today is that the body's resistance is what, above all, matters, not in one disease, or two or twenty, but in *all*. Microbes and parasites of all sorts attack us, and the question is whether we can resist them. Our own cells turn parasitic, and the question is the same. We unknowingly take non-microbic poisons, such as lead, if we work with that metal, and the question is the same.

Alcohol Retards the Power of Self-Cure, by Lowering Resistance

In all of these types of cases, which cover between them practically all the ills that flesh is heir to, alcohol has been proved to lower resistance. The white blood-cells may or may not be concerned, but always some cells or other are concerned, and the essential action of alcohol on all living cells, animal or vegetable, is the same. We have seen how it affects cells of relatively low type, like the leucocytes. In the next chapter we shall see how it affects the cells and functions of the brain; and elsewhere—for the subject is not part of personal hygiene—we shall see how it affects the germ-cells.

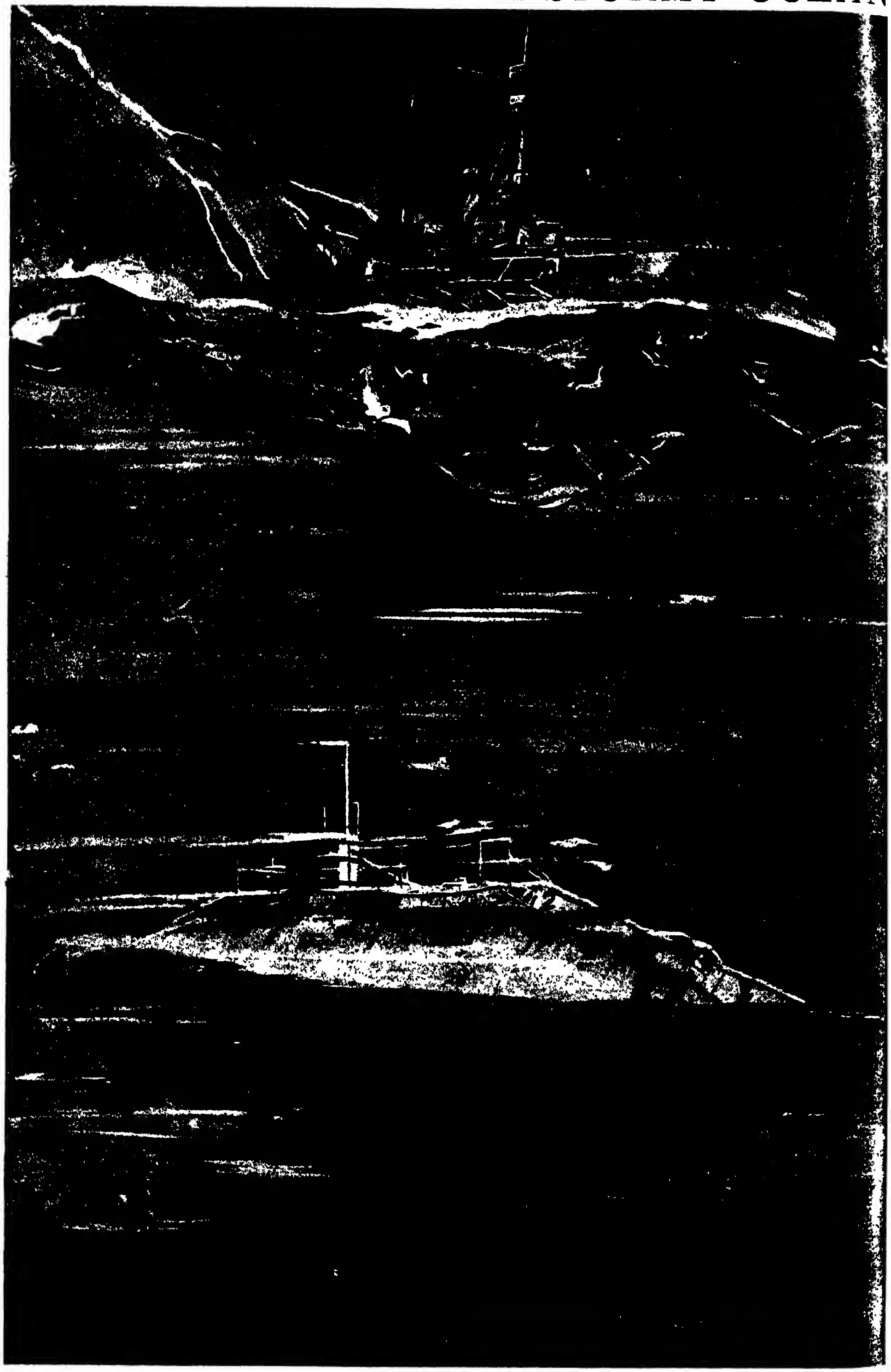
There is no occasion to burden the present inquiry, or any part of such a work as this, with the action of alcohol, in large and frequent doses, upon the cells and functions of the stomach, the liver, the kidneys, and so forth. Facts of that kind are familiar to every medical student, can be conveniently studied in the *post-mortem* room and the laboratory, and can be taken for granted by the rest of the world. The science of today is much more concerned with subtler actions of alcohol, which do not involve these gross changes in bodily structure, and were therefore much longer in being revealed. The microscopic study of disease, which did so much in the nineteenth century, could not go so far; but its chemical study, which is more of our own time, can deal with the deeper questions of susceptibility and immunity and resistance, upon which, above all, the maintenance of life and health depends. The appalling practice of which a certain Dr. Todd was the nineteenth century champion has gone for ever; the public would no longer allow itself to be drenched with alcohol as in those days.

The Discredit Cast on Alcohol by Methods of Physical Training

The teaching in the medical schools has been transformed within a decade. As many have pointed out in this country and America, the popularity of athletics and physical culture has helped and complemented the advance of science. No reputable trainer of today allows alcohol, and the pupils of the others do not win their events. Several municipalities in this country have followed the French example and issued posters on the subject, embodying the best modern knowledge. That of Sheffield is an excellent recent example. Temperance is becoming fashionable, and people will be willing to believe it true.

The psychology of the subject has its own special aspects, and may conveniently be dealt with next; for though the hygiene of the mind is not next in order, the action of alcohol upon cerebral and mental functions cannot be left undiscussed at this point, especially as it directly leads us to the final question of treating the alcoholic habit or tendency, the exploitation of which by commercialism, secretly using alcohol to "treat" alcoholism, is as ugly a chapter as any in the life of a half-educated people.

THE SILENT SHIP IN A STORMY OCEAN



A SUBMARINE MAY LIE AT PEACE WHILE A GREAT DREADNOUGHT TOSSES UNEASILY ABOVE

PATHWAYS UNDER THE SEA

The Story of the Invention, Construction, and Improvement of Submarines and Torpedoes

COMING WONDERS OF UNDER-SEA TRAVEL

When the progenitors of the human race emerged from the waters to conquer the earth, they sacrificed the mastery of the deep. Man is practically the only mammal incapable of swimming naturally. For thousands upon thousands of years he has been seeking to regain not, indeed, identically the powers he has surrendered in relation to the waters, for he does not covet a return of gills and swim-bladder, but of such means as shall enable him to regard the sea as a highway rather than as a barrier, as a helpful medium of travel, instead of interposing menacing bounds which he may not pass. Long before the dawn of history he learned to sail the seas. He was a mariner before he was a scholar, an adventurous navigator before compasses were fashioned or natural laws understood. He began his contest with the elements without reckoning their nature, or troubling to codify laws for their control. He learned to swim, and to sail and steer a raft by intuition as wonderful as that by which Archimedes, in his flooded bathroom, grasped the secret of specific gravity. Long before Archimedes wrote his immortal treatise upon the pressure exerted by water, untutored men had been accustomed to test and try the matter in actual practice without a rule to guide them. They had not only made themselves mariners; they were by way of becoming sub-mariners.

This greatest of all the conquests won at sea—the power to float, enclosed and safeguarded, beneath the surface of the water, a feat which has become really practicable only within the last decade or so—this conquest was gained in part by the ancients before the mighty genius of Archimedes illumined the world. Aristotle, a century earlier, had made it clear that in his day the idea of submarine locomotion had possessed the mind of his contemporaries. He writes of a submarine vessel which he declares to have been employed at the siege of Tyre. And of an air-tube, like the trunk of an elephant, by means of which divers drew air-supplies from above the surface of the water. Alexander the Great is stated to have made use in warfare of the services of men who were equipped with a contrivance that enabled them to walk at the bottom of the sea; while Pliny preserves record of a diving apparatus. Thus, during four centuries leading up to the Christian era, men, having grasped the secret of riding the waves, were seeking, more or less successfully, to tunnel them, as it were. We find no trace of the idea for another thirteen centuries, when Roger Bacon, by his allusion to the air-tubes used by divers, shows that the plan for breathing and moving beneath the water, if it had been lost, had come again into being. The originality of idea and the courage to put the plan to the proof were there; only the means were lacking. These pioneers risked no more than the gallant fellows of our Navy of today, for a man has but one life to lose, but they risked as much.

For we have ample record of submarine experiments which proceeded beyond plan and model to actual service in the water. We might demand better evidence in a court of law than that of the good Bishop Claus Magnus, who states that certain pirates of his time made use of leather vessels, "for the purpose of going wherever they wish, either above or below water." Although he states that "In 1505 I saw two of these leather boats or skiffs in the Cathedral Church of Aslöe, in the western porch," we have no testimony as to how these performed their diving feats. It seems a fact, however, that in 1538 a diving-vessel was exhibited at Toledo before the Emperor Charles V., and that, twenty years later, the Venetians made use of some form of

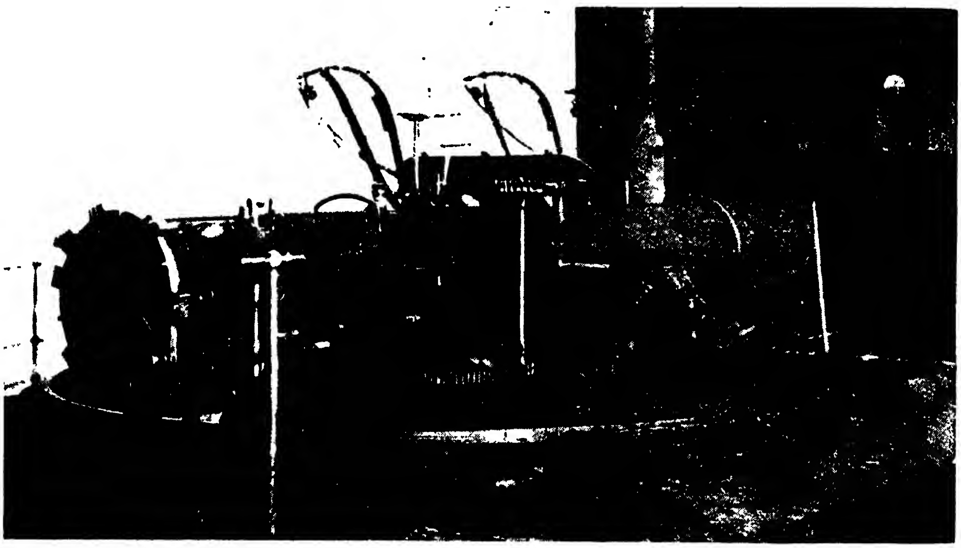
submersible boat to raise a sunken galleon. Another twenty years elapse, and we have a note of the plan of William Bourne, one of Queen Elizabeth's naval gunners, who projects a vessel "that may go under the water unto the bottom, and so come up again at your pleasure." The vessel was to contain three compartments, one above another, the upper and lowermost water-tight, the middle one pierced with holes and provided with two longitudinal bulkheads, which latter, when drawn inwards, admitted water, and caused the boat to sink, but which, when pushed out hard against the perforated sides, expelled and excluded the water, so enabling the vessel to rise.

James II. is said to have encouraged a certain Dutchman, one Cornelius Drebble, to make a submersible boat, which boat is declared to have dived in the Thames, carrying "12 rowers besides passengers." A warrant is extant, dated 1626, from "His Majestie to the Master of the Ordnuance, for the makyng of dyvers water mines, water petards, fforged cases to be shot with fireworks, and boates to goe under water." And one of the following year to the Duke of Buckingham for the delivery of "360 fforged iron cases with fireworks, 50 water mynes, 290 water petards, and two boates to conduct them under water for H.M. present services to goe with the fleete."

Thus century after century the idea persisted. Men were determined to emulate the fishes. Steam power was unknown, so they had recourse to manual labour, working their craft by means of oars and an anticipation of the screw propeller, which it took many years to render acceptable to the builders of ships for ordinary ocean transport. David Bushnell, an American, was the first of whose exploits in modern warfare we have any clear trace. He invented a small vessel to carry one man, which could be submerged, worked with an oar and steered by a primitive rudder. He very nearly succeeded in 1776 in torpedoing a British man-of-war. He got beneath her, but had not strength or skill enough to affix his explosive, which happily drifted clear, and, answering its time-fuse, burst an hour late, well away from its intended victim.

Robert Fulton, of steamship fame, was the next prominent worker in the field. His experiments were carried on in France, with the knowledge of Napoleon. Strange that the wonderful mind of that remarkable man never grasped the potentialities of either the steamboat or the submarine. Had Fulton succeeded in converting him Napoleon might have known no defeat at the Nile or Trafalgar; and Waterloo, if ever fought, might have had a different issue. He thought at one time after his final defeat of escaping from France to America, it will be remembered; and a submarine was actually built in the United States, with a view to rescuing him from St. Helena, but it never set sail.

Fulton's boat, which was exhibited with success, furnished the outline that has



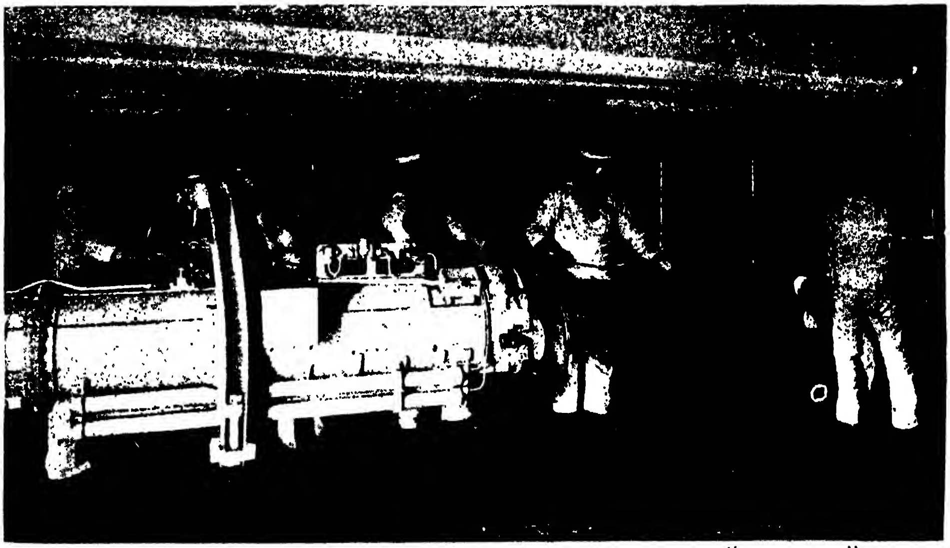
A TORPEDO-DISCHARGING TUBE ON THE DECK OF THE DESTROYER "SWIFT"

been more or less closely followed for submarines. It was cigar-shaped, carried a small conning-tower, and was steered by a rudder. Propelled by hand, it was fitted with a mast for use on the surface, and, carrying air at high pressure, it enabled him to remain for several hours under water in the vessel, and to torpedo sunken craft. But the time was not ripe for the acceptance of the invention, and Fulton turned to more profitable work. A German inventor, Bauer, who received the patronage of the Prince Consort in England half a century later, was not more successful, nor was a French vessel launched at Rochefort and propelled by compressed air.

In 1864 the submarine became a practical factor in war when the Federal frigate "Housatonic" was torpedoed and sunk off Charleston by a Confederate submarine boat. Never before had such a thing happened, and, by the way, the feat has never been repeated. The fatally successful boat carried its torpedo upon a spar, and the explosion was as dangerous to the attacking side as to the attacked. It was not until the torpedo proper attained to a higher state of perfection that the idea of the submarine again became seriously considered. Then it was intended that torpedo-boats should be submarines. And so we come to the history of our own times, with the rival schemes of Holland in America and Nordenfelt in Europe.

It will be convenient to pause at this point to consider for a moment the mechanism of this torpedo which has called the submarine vessel of war into being. It is in its highest form essentially a huge contact bomb, eighteen inches in diameter and over sixteen feet in length, costing hundreds of pounds to make, comprising within its interior some of the highest refinements of mechanical contrivance, and capable of sinking at a single blow a battleship on which close upon a couple of millions sterling may have been spent.

It has caused the construction of the three most modern war-craft—the torpedo-boat, the torpedo-boat destroyer, and the submarine. It has brought the gyroscope into use as a practical mechanism, and, by so doing, paved the way to a triumph of peaceful communication in the shape of the mono-rail train. Had there been no torpedo there would have been no serious application of the gyroscope to the arts of war, nor to the problem of railway transit.



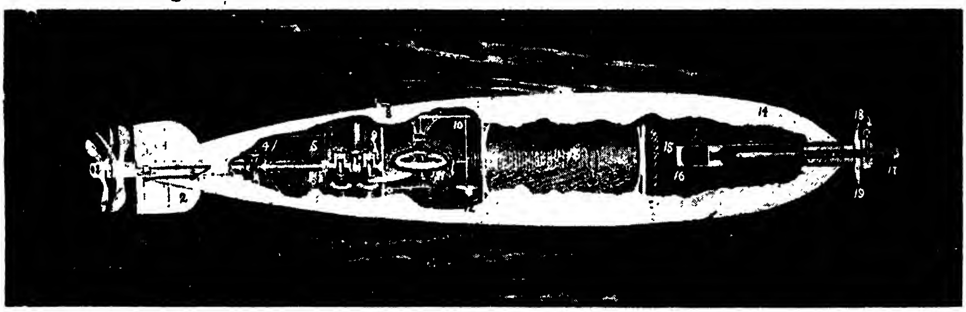
RUNNING A TORPEDO INTO A DISCHARGING-TUBE ON H.M.S. "DEFIANCE"

The torpedo was cradled in the cumbersome explosives which Bushnell and Fulton fired so long ago beneath the water. Those, if successful, would have been as effective as the newest torpedo, with this difference: the new explosive is sent unattended upon its errand; the old had to be taken to its victim. The idea lay dormant after Fulton's day until the American Civil War. Then it was revived. Primitive torpedoes were rigged up on spars projecting from small vessels, and upon being brought in contact with the object of attack were exploded by means of an

electric battery. Often the aggressors perished with the assailed, but no fewer than thirty-four vessels were blown up by torpedoes during the war. Nothing further happened, however, until an Englishman named Robert Whitehead, a native of Bolton-le-Moors (born 1826, died 1905), settled at Fiume, and took in hand the unworkable scheme of an Austrian captain, and from it evolved the wonderful Whitehead torpedo. It would be profitless to consider all the steps by which the invention has been brought to perfection, but we may glance briefly at its principal modern features.

The torpedo is a metal tube shaped like a cigar, divided internally, by steel bulkheads, into a succession of watertight compartments. At the front is the explosive head, containing damp gun-cotton and a mechanical firing arrangment known as the pistol. The latter is a rod which, on contact with a resisting substance, is driven in upon a detonator, which fires a primer, by which the gun-cotton is in turn exploded. Behind this compartment lies a second, in which air compressed to a pressure of 2000 pounds to the square inch is stored. This chamber is practically the boiler-room of the torpedo, and applies motive power to the four-cylinder engine by which the projectile is driven through the water. In order to gain still further power than was originally obtainable, the compressed air, as it passes by way of valves to the engine, is heated, so increasing the speed and range of the projectile.

Next to the air-chamber is the balance-compartment, in which is the gyroscopic control of the air-motor by which the steering rudders are directed. Direction thus governed has this result: that the course of the torpedo having been fixed before discharge, should the projectile be caused to dip, or to rise in the water, or be deflected, the gyroscope actuates a motor, which in turn operates rods connected with the rudders, so at once correcting the divergence from the course originally set. Although the method of steering thus baldly described sounds simple, it is in reality highly complicated and refined. The motor mentioned is only a few inches in length, but the power it exerts by means of compressed air is such that a pressure of half an ounce exerted by the steering-gear produces a pull of 160 pounds on the rudders. Still farther back we have the buoyancy-chamber and the engine-room of the torpedo, in which latter division the engine, driven by compressed air, develops a very high horsepower. The balance-chamber, already mentioned, determines also the depth at which the torpedo shall run, whether the course be five feet or twenty feet in the water.



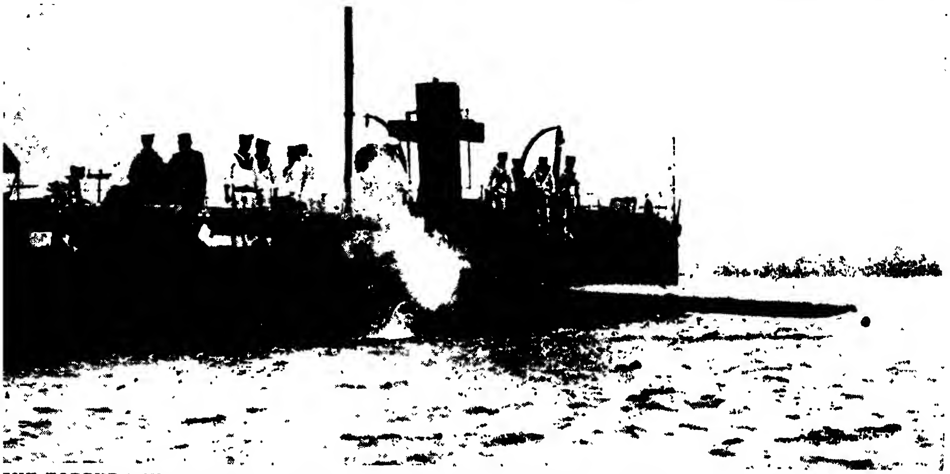
A PICTURE-DIAGRAM OF THE COMPLEX STRUCTURE OF THE TORPEDO

1, Twin screws revolving in opposite directions; 2, vertical rudder; 3, horizontal rudder; 4, bevel gear; 5, propeller shaft; 6, buoyancy chamber; 7, starting gear, the engines of which are set off automatically as the torpedo leaves the tube; 8, starting pin; 9, engine chamber; 10, balance chamber; 11, gyroscope; 12, a weight which controls the depth of running by acting on the horizontal rudder; 13, compressed air chamber; 14, war-head; 15, gun-cotton charge; 16, primer of fulminate of mercury; 17, striker, which, driven in, fires the charge; 18, safety-pin, withdrawn at the moment of firing; 19, fan revolving in the water to unscrew and free the striker.

The tail of this terrible fish contains the wheel gearing for driving the two propellers (which move in opposite directions, and so prevent the torpedo from revolving in a circle), the "fins," and the rudders. The whole bristles with appliances introduced as safeguards, some to prevent the missile from becoming effective until it has passed a certain distance from the vessel which launches it, and so sending its owners to destruction; some to prevent the engine from racing and to maintain a constant speed; some to show a light when the torpedo is used in practice; some to keep it afloat should it fail to explode; some to ensure its penetrating the torpedo-net spread to entangle it as it nears a ship.

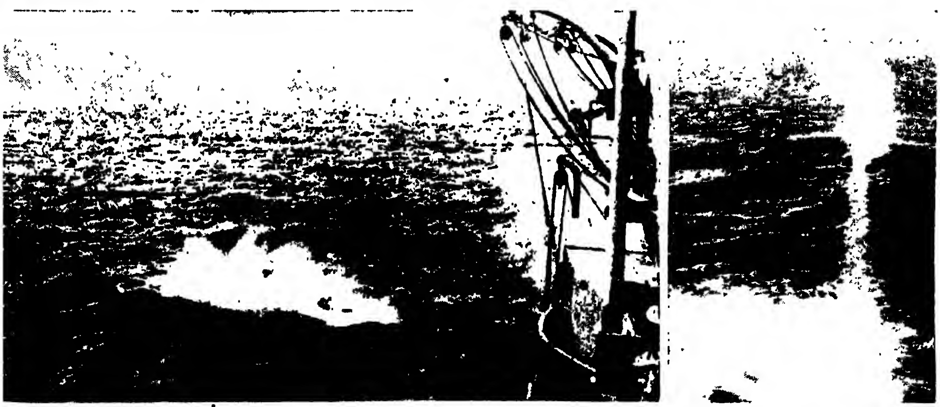
The torpedo can be fired from above water, but the drop to the sea in such cases

LAUNCHING A TORPEDO ON ITS COURSE



THE TORPEDO HURLED BY COMPRESSED AIR FROM ITS TUBE ON THE DECK OF A TORPEDO-BOAT

THE TORPEDO AS IT TOUCHES THE SURFACE OF THE WAVES



THE SPLASH OF THE TORPEDO, AND ITS BUBBLE-MARKED COURSE BELOW THE SEA

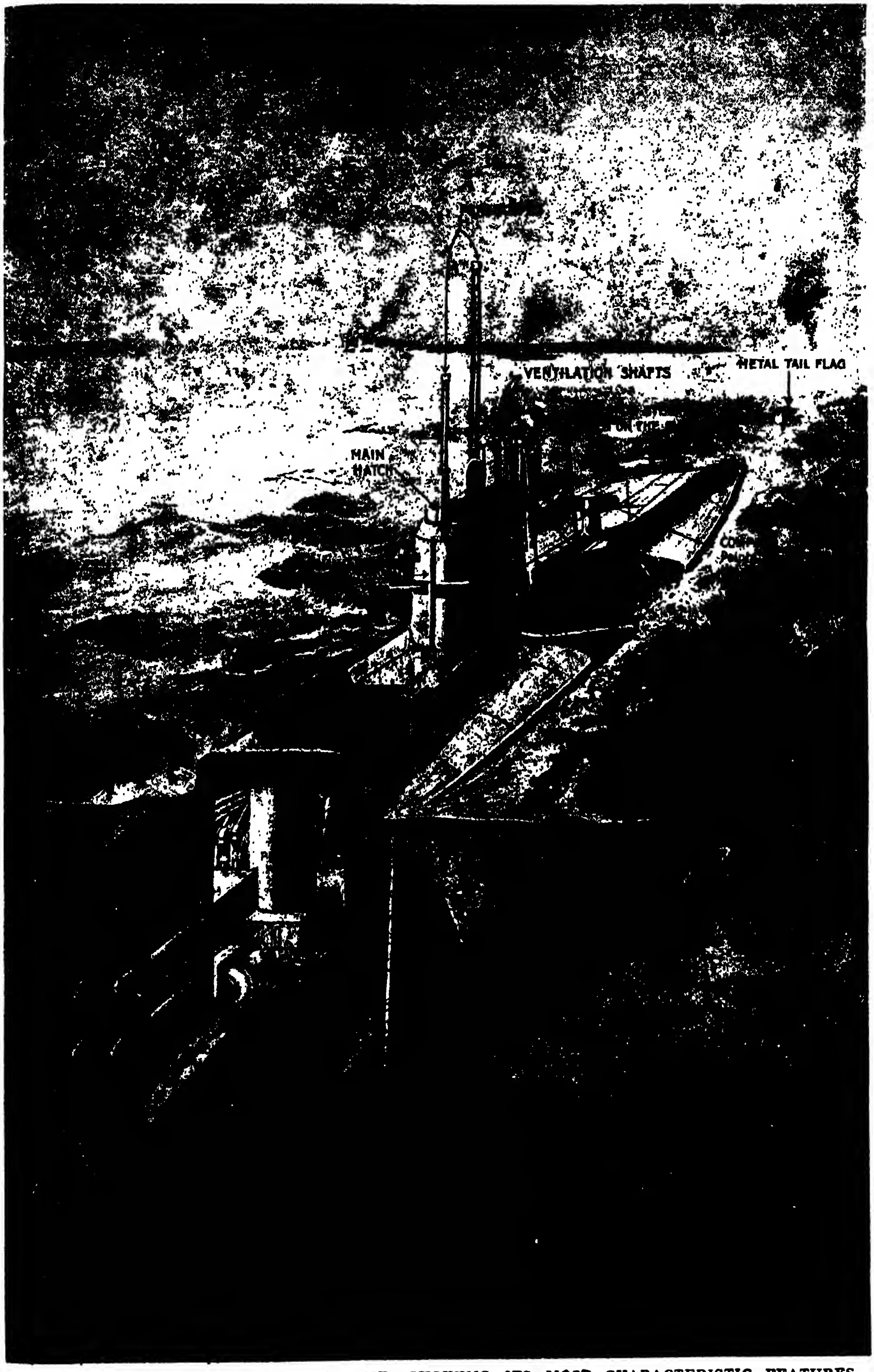
is apt to injure the delicate mechanism of the missile, and the safest plan is to launch it below the water. It can now travel a distance of upwards of 2000 yards, at a rate of considerably over thirty knots an hour, without once showing above the water. It is discharged from its tube by an officer in the conning-tower, who, by touching an electric button, ignites a charge of cordite, which thrusts the torpedo from its tube, and, by setting in action various mechanical contrivances, makes it self-propelling to the end of its journey.


THE WIRE NETS HUNG ON BOOMS AROUND A WARSHIP TO CATCH TORPEDOES

The Brennan torpedo is not unlike the Whitehead in general features, but it is driven by an engine on shore. This torpedo carries in its interior two drums of fine piano-wire, the ends of which are connected to the two drums of the shore engine. The revolutions of the engine-drums cause the wire in the torpedo rapidly to unwind. The revolving reels cause the screw propellers of the torpedo, in turn, to revolve, so driving the missile on its way. Steering is perfectly controlled by the wires, which actuate vertical rudders. To accelerate the speed of one drum causes the connected propeller to turn the faster, so altering the direction of the torpedo. The Brennan invention ha[s] been generally employed for coast defenc[e] for the harbours and narrow waterways [o]f the British Empire, but the essential wire[s] are fatal to its adoption for moving ship[s] which might become involved and blow[n] up by their own projectiles. The Whitehead is therefore the torpedo for the war vessel and the submarine; and it is this deadly weapon which has brought the last-named into the fleets of the world.

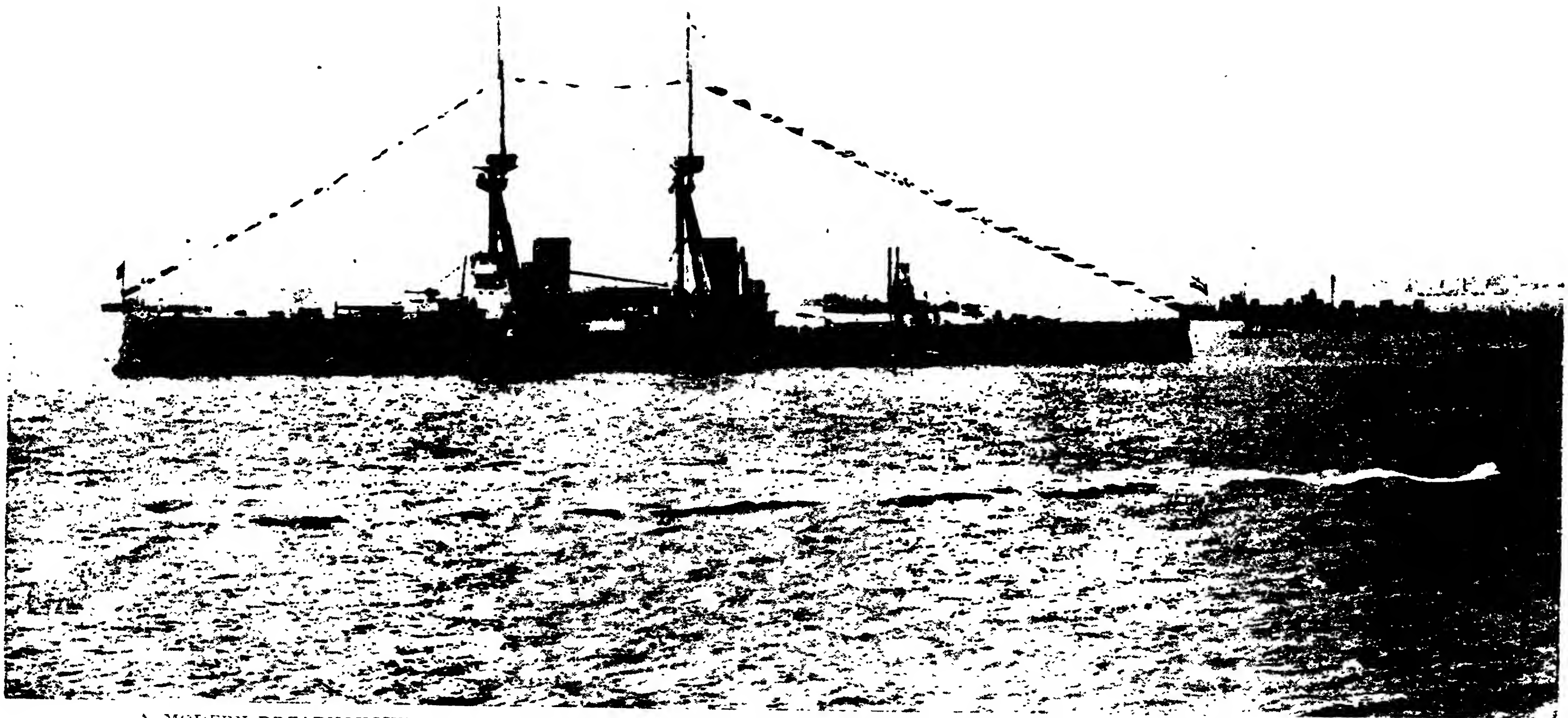

A TORPEDO CAUGHT IN A NET

Seeing that nearly forty years have elapsed since Whitehead began his experiments with the modern torpedo, it may seem strange that the submarine vessel designed to give it its utmost power failed, after all the trials already narrated, to arrive before. In point of fact, it could hardly have matured a day earlier. Men had been groping for two thousand years for a successful scheme for the design of a boat which should serve them as a coast defence, and as a method of safe transport on the floor of the sea where buried treasure and secrets of science lay. The simple truth is that until the other year the means were not available for the building of a satisfactory submarine. What are the requirements?



A SECTIONAL VIEW OF A SUBMARINE, SHOWING ITS MOST CHARACTERISTIC FEATURES

THE AGE-LONG STRIFE OF FORCE & GUILE—A MONSTER OF THE DEEP & HER SECRET FOE



A MODERN DREADNOUGHT BEING ATTACKED BY A SUBMARINE, WHOSE PERISCOPE ONLY IS VISIBLE ABOVE THE WATER

The vessel must be able to travel on the surface of the water. It must be able safely to descend to a sufficient depth to enable it to clear the hull of a ship. It must be capable of preserving longitudinal stability under water, otherwise it would dive to destruction. It must be water-tight and air-tight, yet men within it must be able to breathe and move and live, during submersion, in comparative comfort. Finally, it must, after diving quickly, be able swiftly to ascend. It is a mistake to suppose that any epoch-marking discovery has been associated with the recent great development of the submarine. The main secret was mastered ages ago; only the materials and methods have been bettered. The little that means so much was lacking.

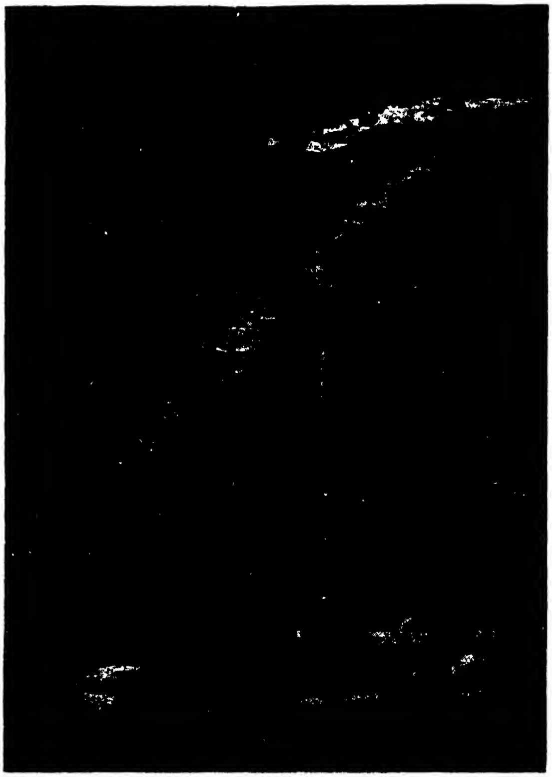
The transition from manual to mechanical power of propulsion had already been effected during the American Civil War, steam and compressed air both having been tried. When, in 1875, Mr. J. P. Holland began his famous sequence of boats, quite a mass of data had been gathered from the experiments of pioneer ventures; and Mr. Nordenfelt, his famous Swedish rival, although he secured the attention of the naval world for a number of years and actually sold some of his creations to more than one Power, seems, in the light of present-day knowledge, to have made his task unnecessarily difficult. French engineers followed, in 1888, with the first of their submarines; and Great Britain waited until 1900 before committing herself to any expression of approval. The British attitude had been all along very much that defined in the dictum of Admiral Lord St. Vincent when consulted by Pitt, who was impressed by Fulton's invention. " Pitt is the greatest fool in creation," said the bluff sailor, " to encourage a mode of war which those who command the sea do not want, and which, if successful, would deprive them of it." The race was left, therefore, between America, Sweden, and France; and, brilliant as have been the triumphs of France, we must award the palm to our American cousins, to whose inventor, Holland, we are indebted for the earliest of submarine craft.

CHARGING THE ELECTRIC STORAGE BATTERY THAT PROPELS THE SUBMARINE WHEN SUBMERGED

When America began seriously to consider the question of submarines for her Navy in 1885, she invited Nordenfelt and Holland to submit designs. The Nordenfelt boats, of which several were built, were driven by steam. When the boat was about to dive, the chimney had to be taken down, the fires put out, and the reserve steam used for propelling the boat beneath the surface. In order to get down, water was drawn into the ballast-tanks, and this increase of weight was accompanied by the work of horizontal propellers, placed one on each side of the boat. The two forces combined to sink the boat in a horizontal position, for Nordenfelt could not believe that any submarine could safely attempt to descend or ascend at an angle.

The boat was a failure, owing in the main to her lack of stability. Anything which caused her for an instant to deviate from the horizontal made the water in her boiler and ballast-tanks surge violently to and fro, and so increased the angle of inclination. She was perpetually working up and down, we are told, like a scale-beam, and no human vigilance could keep her on an even keel for half a minute at a time. The only occasion that she fired a torpedo she nearly stood vertically on her tail; while the unexpected wash from a boat, as she was about to descend, filled her open conning-tower with water, and caused her to sink like a stone. Only the immediate blowing out of ballast-water restored her buoyancy and enabled her to rise and so save her crew.

Mr. Holland, after many trials, all on the right lines, designed a boat driven by a petrol-engine, fitted with ballast water-tanks and diving-rudders, with electric batteries for use when submerged, with abundant reserve of compressed air for breathing. This boat did not sink horizontally, as the various Nordenfelts had sunk; she descended and ascended at an angle, and maintained her fixed depth by means of her lessened buoyancy and the action of her horizontal rudders, this latter means being effective, of course, only when the boat was moving. That, in the briefest outline, was the "Holland," with which the British Government in March, 1901, announced its intention to experiment. The Mistress of the Seas had to buy her first batch of submarines of an American inventor! True, they were constructed in England, but the design was American, and permission to build the boats was given by an American firm. The policy of deliberation, it may be added, has been abundantly justified in the opinion of all the experts. From being among the latest to enter the race for submarines, Great Britain has made herself mistress of the finest fleet of these craft in the world.



A TRAIL OF DEATH FROM A SUBMARINE

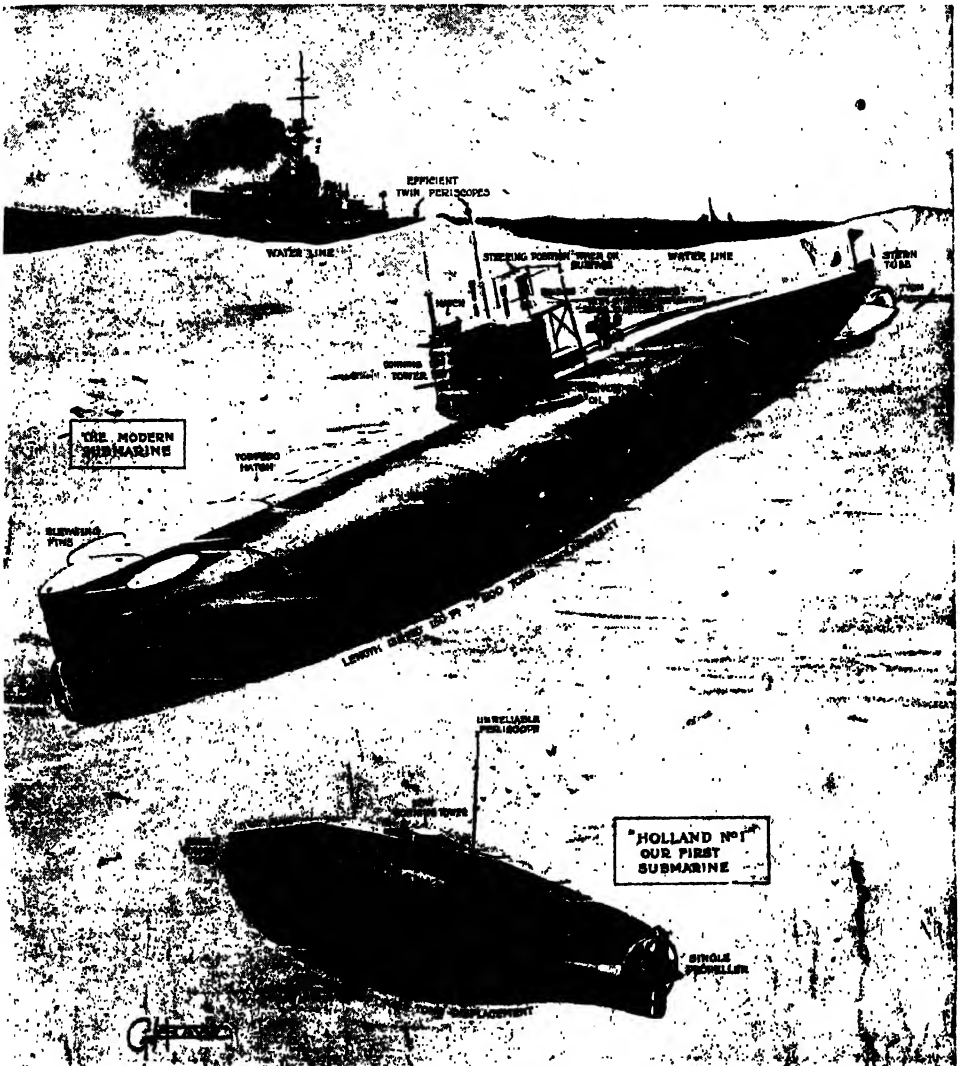
The submarine is seen rising to the surface to note the effect of the torpedo it has just discharged. Its track towards its objective is marked by the rising bubbles of compressed air.

Great Britain waited while other nations were experimenting, bought the first practicable idea, and has improved it out of all recognition.

Young as we are as a submarine-owning Power, we have already outgrown many mistakes. We began with small craft fitted with gasolene-engines. Gasolene gives off deadly fumes in a closed chamber, and caused explosions. We took up the petrol-engine with similar result. That, in turn, is being abandoned, and the heavy-oil internal-combustion engine has taken its place. Every year has brought an improvement in the internal-combustion engine. Almost as great an advance has been made in the electric storage battery. The engine propels the boat while it is on the surface, and also generates electricity, which is stored for use when the submarine dives. It was the absence of these two inventions which made all earlier submersible craft impossible. Compressed air was inadequate for the swift movements required of a submarine. Steam, even if it had no other objection, required the presence of a large cargo of coal, and not only limited the vessel's sphere of activity, but, with the diminishing weight, affected the equilibrium of the boat, in spite of careful calculations as to the admission of compensating ballast-water. Until the internal-combustion engine was perfected and a reasonably effective storage battery secured, the submarine was never worth consideration except for the briefest spells of work. Today a British submarine carries oil-fuel enough to motor 4000 miles on the surface, while its storage batteries enable it, if necessary, to travel at the rate of eleven knots an hour beneath the surface for forty-eight hours at a stretch without once rising to the surface. The supply of air carried in reserve is sufficient for that period.

Another difficulty which has been overcome since Great Britain entered the field is in regard to seeing and steering. At first the submarine was like a blind fish in a Kentucky cavern, but lacking that

creature's sensitiveness of touch. Moreover, the electric currents with which the vessel is charged made the only possible method of steering under water, by compass, hopelessly erratic. The periscope has given eyes to the submarine, and the gyroscope compass has rendered her free from difficulty as to electric currents. form, the deck, and rising above the deck is a prominence, looking a distance like a hump. This prominence is the conning-tower of armoured steel, but lighted by windows through which the navigating officer can see his course when the vessel is running only half submerged. Until terrible accidents caused by water pouring down the

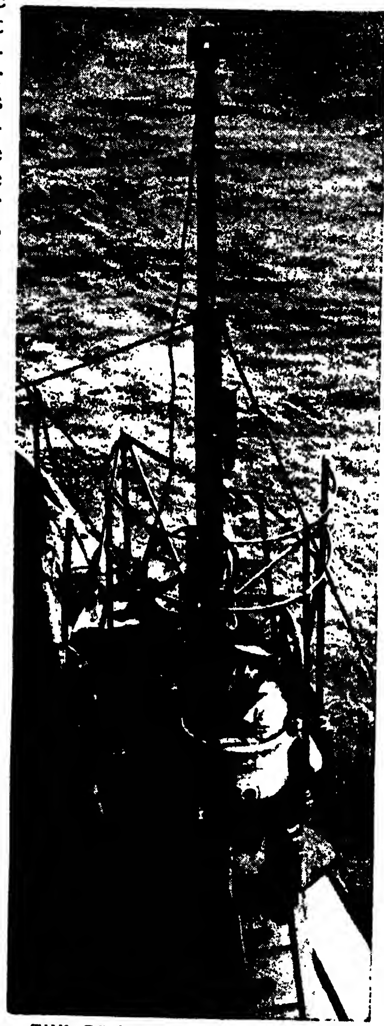


TEN YEARS' PROGRESS IN SUBMARINES—THE HOLLAND AND THE "D" CLASS COMPARED

The actual mechanism of the modern submarine is one of the most closely guarded of secrets. Every man concerned in her structure is sworn to secrecy, so that only general details can be given. Submarines are constructed in the form of gigantic fish of metal. The body of the fish is the hull of the vessel. Upon its back is a small plat-hatch of an unclosed conning-tower brought an amendment, this tower led directly into the body of the vessel. Now, however, the hatch at the top of the tower, through which the crew enter the vessel, has a corresponding device at the bottom, so that should a sea break over the open top it cannot penetrate into the interior. But in

case of accident, as has happened, the man on look-out duty there remains fastened between the two hatches, a prisoner.

When the craft is about to dive, the conning-tower is closed, water is admitted into the ballast-tanks to lessen buoyancy, the engine is switched off, and electricity becomes the motive power and drives the propeller. With the electric motors running, the newest boats develop 600 horse-power. As the propeller turns, the diving-rudders direct the vessel downwards. A depth of some 100 feet is said to be possible, but a third or even a fifth of that is sufficient for all ordinary purposes. The equilibrium of the craft is maintained by various secret automatic appliances, by pendulum, and by ballast contained in what is known as the trimming-tank. Innumerable instruments keep the crew informed as to the conditions immediately surrounding their little world. Sight does not assist, except when the periscope is consulted. The sea itself is utterly opaque for the submariner. Searchlights are useless. The vessel itself is brilliantly lighted by electricity, but the water is a gross, black void. We have failed to equal the feat of an octopus, recently described, which employs one half of an enormous compound eye for projecting a powerful phosphorescent light, and the other half of this astonishing eye as an organ of vision. In time, no doubt, we shall overcome this difficulty. At present news comes only from the surface by way of the periscope—a series of prisms by means of which a picture of the surface is reflected down an elongated telescopic tube, to be viewed by the eye of the man below. The newest submarines have two of these admirable instruments. One is in charge of the man who looks for objects in the immediate neighbourhood of the submarine; the other tells the tale of a wider horizon to a second look-out man.



THE BRIDGE OF A SUBMARINE

A close view of the conning-tower, steering-wheel, periscope, and light. The conning-tower is only large enough to admit one man at a time.

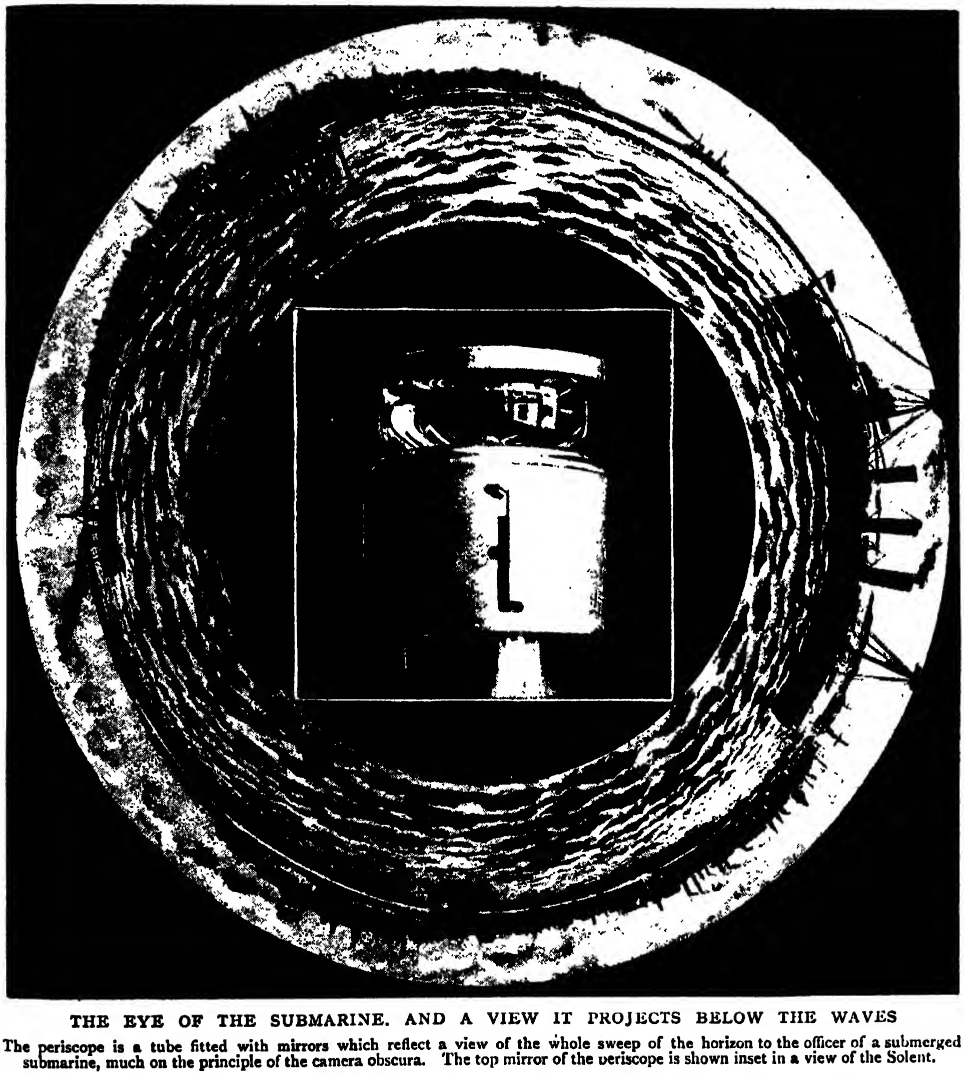
Compressed air supplies the atmosphere of the vessel when below the water, and also discharges the torpedoes which the vessel carries. Our most modern boats carry four torpedo-tubes, and the firing of these is accompanied by a triumph of compensatory balance. The earlier craft were so unstable that the mere movement forward or backward of one of the crew might send the vessel diving to the bottom; and we have seen what happened when the Nordenfelt discharged her only torpedo. Now, however, as the terrible projectile leaves its tube, water is admitted and passed from tank to tank with such precision and speed that balance is never for an instant affected.

Within the vessel the crew, which consists as a rule of about fourteen officers and men, cook their food in electrically heated ovens. They partake of the same rations, share practically the same quarters, carry their lives in their hands every minute of every hour, but declare themselves the happiest crews in the Navy. Conditions below are now so improved that it is no longer necessary to carry white mice to warn the men of the presence of carbon monoxide in the atmosphere: the carbon monoxide is no longer there.

The submarine has now passed its experimental stage. At first it was regarded simply as a means of coast defence, but it is rapidly attaining to the dignity of an ocean-keeping vessel. In the unhappy event of war, the submarines might have to take the open sea as assailants. Armed with their four torpedo-tubes and their quick-firing guns—these latter mounted on a disappearing platform forward of the conning-tower—they would accompany larger ships

to sea. Upon the enemy being sighted by one of the greater warships, instructions would be given by wireless telegraphy to the submarine, which, led like a dog of war to the quarry, would dive out of sight; then, proceeding eighteen or twenty feet under water, with only the periscope momentarily peeping above the waves, would steal upon the enemy, and, the right distance having been gained and the exact position ascertained, discharge its torpedoes one after another until the enemy had been sent to its doom. Then the little terror of the seas would creep away again, unobserved as it had come. The potentialities of the submarine are enormous and terrible. The probability is that their size and power will be immensely increased, and that they will in time supersede the gunboat of today.

What their future is to be in peaceful pursuits cannot be guessed; but as knowledge of contrivances which are now State secrets becomes diffused, the submarine must surely be a great adjunct to the diver. Already startling achievements are credited to the Lake submarine, a vessel which runs upon wheels along the bottom of lakes and shallow seas, exploring and retrieving cargoes sunk in moderate depths. The usefulness of these vessels in this direction must, however, be limited through the

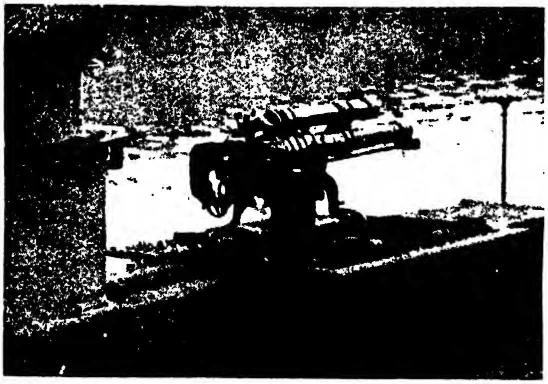


THE EYE OF THE SUBMARINE, AND A VIEW IT PROJECTS BELOW THE WAVES

The periscope is a tube fitted with mirrors which reflect a view of the whole sweep of the horizon to the officer of a submerged submarine, much on the principle of the camera obscura. The top mirror of the periscope is shown inset in a view of the Solent.

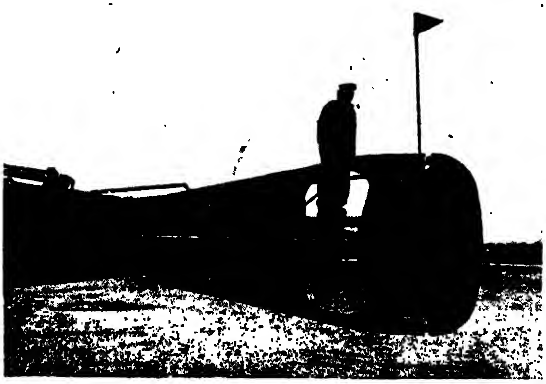
incapacity of the human constitution to withstand water-pressure at more than modest depths.

Among enthusiastic believers in the future of the submarine this type of craft has already been added to the list of competitors for the Channel crossing of the future. We are promised that whosoever will may, at some date hereafter to be named, cross from England to France by submarine, so relieving advocates of the Channel tunnel scheme from further prosecuting their designs, and rendering the projected Channel ferry unnecessary.



A DISAPPEARING QUICK-FIRER—THE NEW ARMAMENT OF THE SUBMARINE

It is unsafe in these days of rapid advance to predict, especially to predict failure, in any direction by which many alert minds are seeking to advance. It would be unwise, in an age which has seen the birth of wireless telegraphy and telephony and the discovery of radium, to hint that cross-Channel passages by submarine will not become common in our time. Aeroplanes flit too frequently across the waters nowadays to make a negative prophecy prudent. The more ambitious the scheme, the more arduous must be the efforts of projectors to justify it, and from effort results proceed—not always in the direction expected. The Channel has not yet been tunnelled, but the works carried out revealed the existence of coal in Kent, which may revolutionise the industrial character of the whole county.



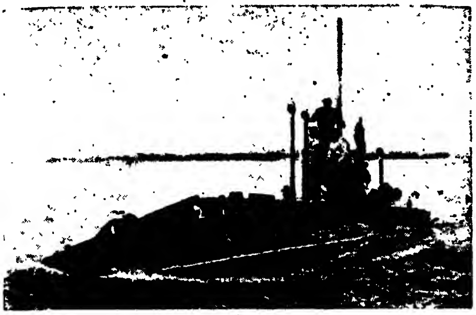
THE RUDDER, PROPELLER, AND REAR ELEVATING PLANES OF A SUBMARINE

Certainly the submarine, if ever it should become commercially practicable, should banish sea-sickness, for the craft, when sunk to its normal depth, experiences nothing of the buffeting and tossing to which the surface-keeping vessel is subjected. An American admiral not long ago kept his submarine fifteen hours under water, and rose, to find a storm raging and the sea at the surface tossing in the greatest fury. The crew had had no idea of any meteorological disturbance. "We've made a mistake in coming up so soon; we'd better go down again, I guess," said the admiral.

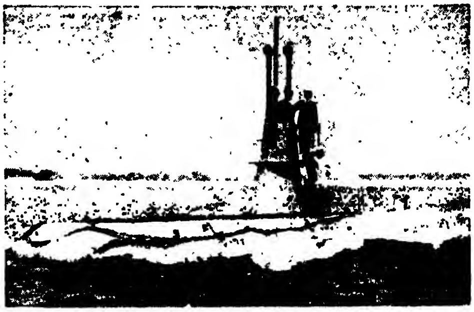
Nor are we to regard this as simply an example of American humour. The submarine can face with equanimity a storm which might be fatal to the ordinary vessel. This aspect of the new craft's seaworthiness was tested by the French naval authorities under grimly dramatic circumstances. A storm, which wrecked a fishing-fleet of 400 boats, swept two battleships from their moorings, and did other very serious damage, was chosen as the occasion for two submarines to quit Toulon harbour and make a mock attack on the French fleet which was at the time steaming home from Corsica. The two boats accomplished their mission in perfect safety, and were declared successfully to have planted one or two torpedoes, quite unhampered by the storm.

The submarine is declared to hold the key wherewith ice-locked harbours may be opened, and frozen rivers and lakes underpassed. One inventor, improving upon this, avowed his intention of proceeding by submarine under the ice to the North Pole. Happily, the advent of Commander Peary at that coveted goal prevented this mad scheme from being attempted. But during the present year we have had a startling illustration of the ability of the submarine to find its way under ice. It

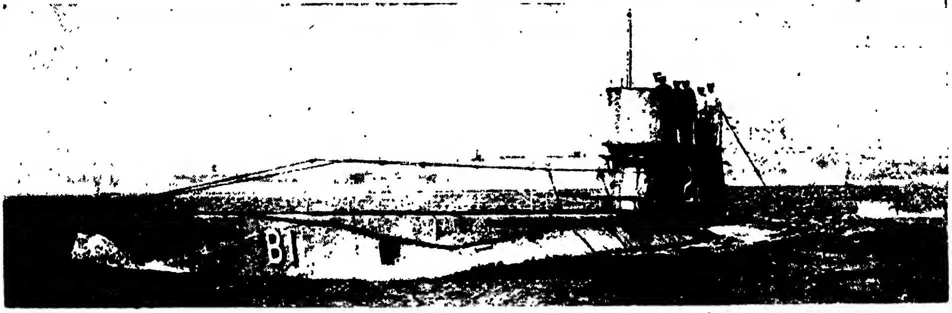
THE EVOLUTION OF THE SUBMARINE



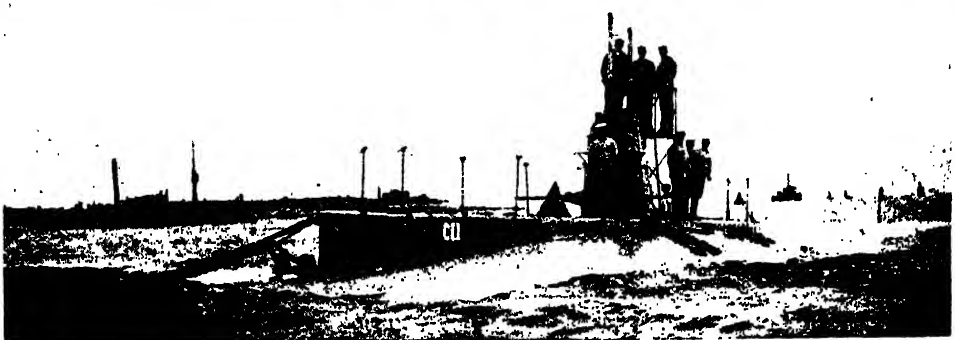
THE HOLLAND SUBMARINE NUMBER 2



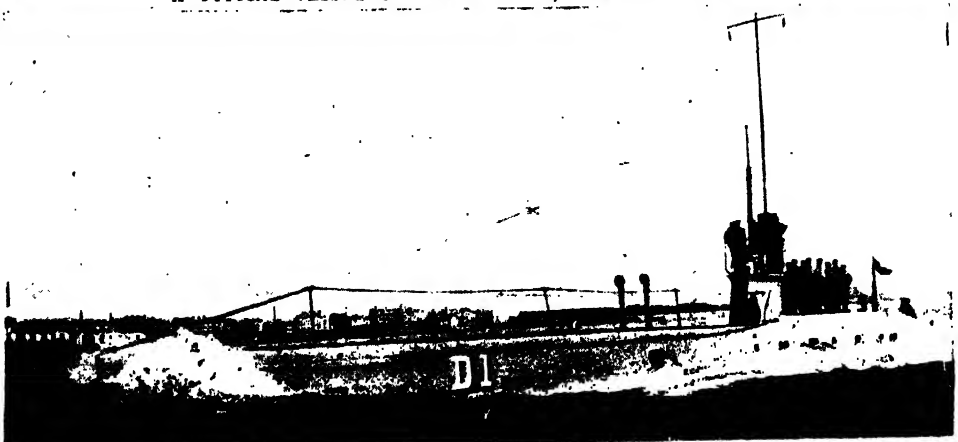
THE A1, COMPLETED IN 1902



THE FIRST VESSEL OF THE B CLASS, COMPLETED IN 1905



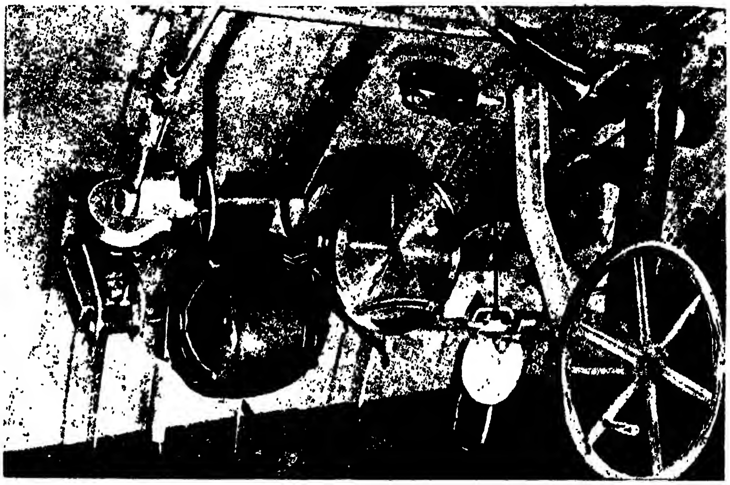
A TYPICAL VESSEL OF THE C CLASS, COMPLETED IN 1906



THE FIRST VESSEL OF THE D CLASS, COMPLETED IN 1909

chanced in February that Chesapeake Bay was, for the first time in many years, frozen over. The United States Navy Department seized the opportunity of seeing how submarines could cruise under ice. The course lay between a point a few miles from Yorktown, Virginia, and the Rappahannock River. At the starting point there was, of course, clear water; the goal was a space at which an ice-breaker had cut a clear passage.

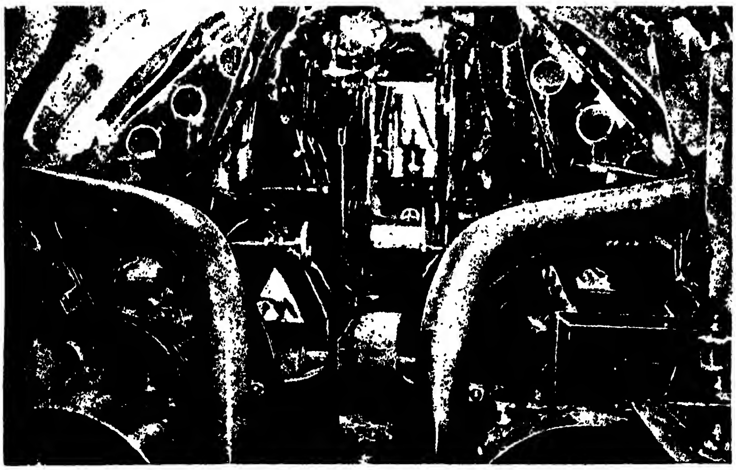
Twenty submarines were dispatched upon the novel and hazardous journey. The conditions were entirely new. Once the boats dipped beneath the ice there was no possibility of rising until clear water was attained. The journey extended over thirty miles, and had to be made entirely by the aid of chart and compass. The majority of the submarines made the perilous journey with safety and exactitude, but a small minority—the precise number is known only to the Navy Department—did not keep their course, and were obliged to make for open water. The achievement of the others, however, was not unnaturally acclaimed a sensational success. The feat was one of the most surprising since a regiment of cavalry captured a ship frozen into the ice of Holland in a war of long ago



THE MECHANISM THAT DIRECTS THE DIVING SUBMARINE

The hand-wheel on the right works the diving-rudders used for steering in a vertical plane. To the left is a gauge whose pointer shows in feet the depth the boat has attained.

Like many other of the famous inventions of man, the submarine has been productive of infinite tragedy as well as of triumph. Although the submarine rudders are remarkably sensitive and effective, and although the mechanism for discharging ballast-water, and so restoring the buoyancy necessary to bring the vessel to the surface, is quick-acting and powerful, many a brave crew has found the submarine but a steel tomb of marvellous but unavailing complexity. Submarine has collided with submarine, with warship, and with steamer. The failure of a valve-spring, causing an escape of petrol, flooded one submarine with gas and rendered its crew helpless.

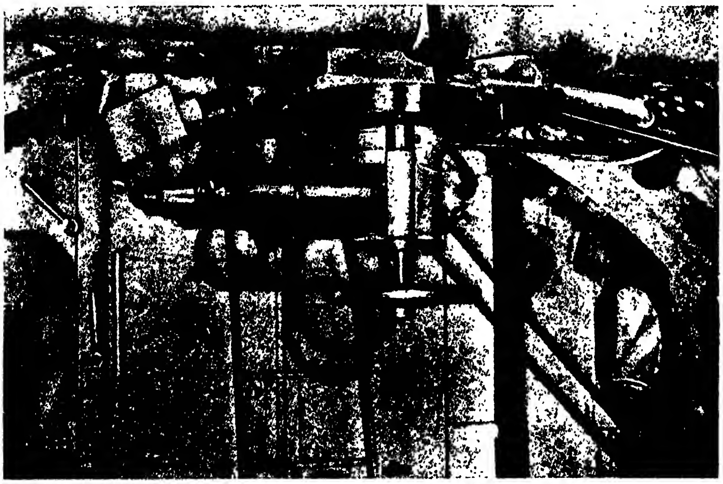


THE ENGINE-ROOM OF AN AMERICAN SUBMARINE

To the right and left of this photograph, which was taken looking aft, are the electric motors which drive the boat when it is submerged.

The starting of a single rivet is held responsible for the loss of another, though quite inadequate reserve buoyancy was, too late, detected The use of a broomstick thrust out of the open conning-tower, as a signal to a sister vessel, led to the shipping of a sea and another disaster. The perils of the submarine are diverse and many.

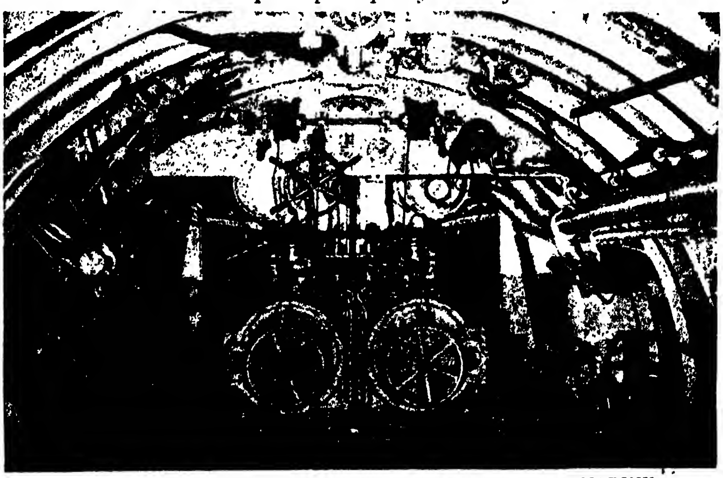
The only consolation is that each accident has taught its lesson. The broomstick signal has yielded place to wireless telegraphy. The petrol-engine is giving way before the heavy-oil engine, from which neither poisonous nor combustible fumes escape. But there remains the fatal blind spot—that period of sightlessness in which the submarine is climbing up from below to thrust her periscope into the air. The submarine is still "blind" when her periscope is submerged; and as she rises she may at any moment strike another vessel which is moving at speed in the same area with himself. The disaster to the French submarine "Vendémiare," involving the loss of her two officers and twenty-three men, which happened while the present article was in preparation, is, unfortunately, only the most recent of several cases in point.



THE BINOCULARS ATTACHED TO THE BASE OF THE PERISCOPE
Looking into these eye-pieces, the navigation officer of a submerged submarine can scan the horizon by rotating the tube of the periscope by means of the hand-wheel.

The submarine must be rendered able to "see" or to "feel" while actually submerged. Possibly the necessary invention will take the form of an electrical device sufficiently sensitive to record the presence and position of a metallic body in the neighbourhood of the submarine. Some such protection is absolutely necessary to the safety of every submersible craft; and it is not unreasonable to hope that Great Britain, as the owner of the finest submarine fleet in existence, may be the source from which this essential life-saving apparatus shall spring.

Whether the perfecting of the submarine will be one of the means whereby the building of sea monsters at an enormous cost will be made futile owing to the mastery over them of this destruction which both "walketh in darkness and wasteth at noonday" is one of the exciting problems of a future that seems near at hand. The bullet killed the armoured knight as an institution without needing to kill many of him in actual warfare; and it is possible that one or two dreadful successes by these deadly prowlers under the waters, combined with the perhaps equally deadly scout from cloudland, bomb in hand, may make the two million sterling floating fortresses of the early twentieth century into relics preserving the memory of one of man's costly mistakes. In the meantime efficiency in submarines and in Dreadnoughts goes hand in hand.



THE TORPEDO TUBES WITHIN AN AMERICAN SUBMARINE
The tubes are in the centre of this photograph of the main floor, looking forward. To the left are the electric motor and gear by which the doors in the nose of the submarine are opened.

THE SCENE AFTER A BLAST IN THE PENRYN GRANITE QUARRY, CORNWALL

The photographs on these pages are by courtesy of The United Stone Firms, Ltd., The Bath and Portland Stone Firms, Ltd., and Messrs. John Freeman, Sons & Co., Ltd.

TREASURES OF THE QUARRY

The Building and Paving Materials Sent into the Cities by the Stone-Workers of the World

STRENGTH FROM EARTH'S CENTRAL FIRES

THE quarrying of stone is, next to agriculture, the most universal of the great industries. Leaving aside the special form of rock which we call coal—a form specialised by its composition, its uses, and the depths at which it is worked—stone-getting and shaping is part of the work of man in almost every quarter of the civilised world. One or other of an infinite variety of stones can be found in each country, and nearly in every district. It is true there are lands of sand, gravel, mud, and dust where but few samples of stone can be used, and yet a sort of civilisation has long existed. It is so, for instance, in the dun wastes of Yarkand and the earlier cities of Mesopotamia, but in the latter land the sun has almost made brick a natural product.

There are, too, lands where timber supersedes stone for many purposes, as on the great plains of Russia and the prairies of the West. But, allowing for these formidable exceptions, the range of the quarryman is remarkably extensive. Not many countries can be named where all the principal kinds of stone cannot be found, hard or soft, smooth or grained.

Though stone is heavy and unwieldy, it is valuable enough to be carried backwards and forwards, to and from all parts of the earth, according to its qualities in use or beauty. Where are Scotch, Norwegian, and Devonshire granites not carried? Who does not know the oolitic limestones of Bath and Portland, the slates of Wales, the gritstones of Derbyshire, the marbles of Italy, the porphyry of Egypt? And all these stones are repeated in many parts of Europe and on the other side of the Atlantic. Such stones are not only used in the regions where they are found, but they are exchanged throughout the world, wherever carriage is feasible.

"Where are you sending these stones?" was asked of the owner of a quarry in the very middle of England, who was having fine gritstones shaped and dressed by machinery. In reply, the stone merchant took two invoices from his pocket, showing that one of the stones was going to Norway (to Trondheim) and the other to Nova Scotia—long journeys over land and sea for such heavy and unwieldy cargo, but quite characteristic of the value put on stone suitable for special uses. The use in the case of these machined Derbyshire millstones was the pulping of wood for paper-making. Such an illustration of the removal, for thousands of miles, of the stones of the earth suggests a new view of quarrying.

What wonder if the instinct that led man to make his first weapons of stone has led him, later, to use the stone of his neighbourhood, or maybe stone from afar, for his own shelter, security, and eventually for his artistic delight?

The chief uses of stone suggest the universality of its working. It is needed for a very wide range of man's activities, beginning early in his civilisation and going on late. Building himself a shelter with the loose stones of the rocky wild would be an early advance on seeking refuge from the weather in a cave. In this way the man could choose his place of residence, instead of depending on the chances of the atmosphere and water in making caves. The stone-built house is common to all lands where stone abounds. Indeed, it has been argued, with some degree of truth, that the original style of architecture of each country is dependent on the kind of stone found there.

This shaping power of stone, of course, is modified, in later times, by competition with wood, which, as civilisation advances, readily supersedes the heavier material if

both are at hand. In Norway, for instance, where there is an equal abundance of wood and stone, wood easily takes precedence, for it is more readily manipulated, and needs far less labour for carriage and for placing in building order. As building, however, grows in size, substantiality, and the need for endurance, stone resumes its importance, and, even in the most modern structures, the important lasting piles of cities are likely to remain of stone masonry wherever dignity is considered as well as convenience.

Where other materials than stone are used for the chief bulk of buildings, it is a common practice to rely on stone for the architectural ornament, for facings, linings, halls, floors, and pillars when an effect of richness is desired, for certain kinds of stone are the natural material for art. The leap from the rock-built cabin on a moor to the statuary of Phidias wrought in Parian marble is a long one indeed, wide almost as the range of man's intellectual progression, but it is all within the limits of the story of stone.

A humbler main use of the earth's rocks is devised in the splintering of them into fragments of various sizes for the making of roads, from the solid pavement of regular setts in cities with a heavy traffic, to the clean garden-walk of the suburban villa strewn with minute "chips."

Then, again, there is the utilisation of the fine grit of some kinds of stone for grinding purposes—sharpening the edge of the more resistant metals till they become keen cutting tools. So home, industry, travel, and art are spheres to which the quarryman's rough labours eventually find their way.

The rocks that can be put to these varied uses are necessarily of widely different characters and origins, and some idea of the geological basis of the stone trade is necessary before we can appreciate the position of the granite rocks, sandstones, limestones, slates, and marbles to which more extended reference must now be made.

THE QUARRIES THAT GAVE ENGLAND A GREAT NATIONAL MUSEUM

From this site, Combefield, Portland, came the stone with which the Victoria and Albert Museum was built; it is also the source of the material for the extension of the British Museum.

Stone divides itself, geologically, into two main groups, first the rocks that have solidified from a molten mass—the igneous group; and, second, rocks that have been formed at later periods from the breaking up of the igneous rocks, the depositing of their material elsewhere, and the action upon it of pressure, or perhaps pressure with fire. Each of these main groups—the once molten rocks and the derived fragmentary rocks—breaks up into a

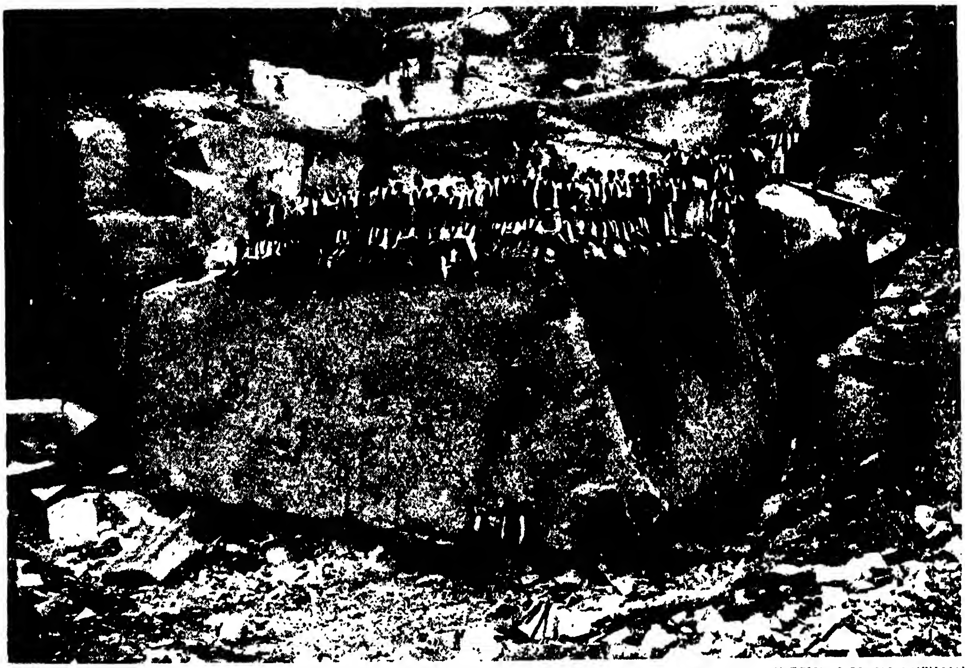
number of easily distinguished varieties, of which we shall name only the most characteristic.

First comes the original mass of igneous rock that, in great variety of composition, has cooled from the molten state. This separates into three varieties. The plutonic type has solidified, and slowly cooled, deep down in the crust of the earth, under heavy pressure, and has often been injected through weaker overlying beds, which have afterwards weathered away till at last their plutonic core is laid bare. The slow cooling has caused the component parts of the molten mass to crystallise as separate minerals, though bound closely together. The characteristic rock of this formation is granite, and it crystallises chiefly into quartz, felspar, and mica.

Next there are intrusive rocks that have solidified in smaller masses from the molten state, and therefore have cooled more quickly, and in consequence have their crystallisation less distinct. Of these hypabyssal rocks porphyry is a typical instance. Next there are volcanic rocks, cooled rapidly on the surface, under less pressure, as in the case of basalt.

The igneous rocks, whether of the plutonic, hypabyssal, or volcanic varieties, furnish the stone that is used wherever strength and endurance are required. These are the rocks that are dressed for paving setts to carry heavy town traffic, or are crushed to various sizes for road-making. But they also are used for building—the city of Aberdeen is almost entirely built of granite—and they can be polished, and under modern methods of dressing and shaping by pneumatic power can even be made available for art work.

Granites are graded into a large number of varieties, according to tests and namings proposed by many students; after the true granites follow granitic rocks of somewhat different composition and texture. till of classification there is no end. The stickler for exactness would confine the granites to such igneous rocks as show predominant crystallisation into quartz, felspar, and mica, with hornblende introduced more or less; and he would exclude syenite, in which the quartz is absent, or nearly absent, with felspar taking its place, and an increase of hornblende. Really, however, syenite is often a tougher stone than granite, except the very hardest varieties, and for all practical purposes is a granite. Indeed, historically it is the oldest of granites, named from Syene, in Egypt,



A COLOSSAL FRAGMENT OF THE QUARRY-SIDE, WEIGHING 2738 TONS, DISLODGED BY BLASTING 110 POUNDS OF BLACK POWDER

near Assuan, though now the name-makers would not classify even the stone of Syene as a syenite, but analyse it into other chemical combinations. Similarly the porphyries and greenstones, though of granitic texture, are differently classified. Broadly, all these igneous rocks have granitic qualities, and when they are good specimens of their kind are hard, tough, will take a polish, and are quarried for all the purposes to which granite is put.

In the British Isles granites abound, from Cornwall to Peterhead. Cornish and Devonshire granites, originally called "moorstone," were at first only quarried from the tors and isolated blocks that were scattered about the uplands, but now they are elaborately quarried and used far away, many specimens of this fine grey stone appearing in London erections. The celebrated Penryn quarry, for example, contributed largely to the Thames Embankment wall. The stone of the Lamorna quarry (Penzance district) has a green tinge and is of a porphyritic variety. Luxullian stone from central Cornwall is got in small blocks from isolated rocks, and has pink (felspar) colouring on a black (tourmaline) ground. It can be seen in London in a place of high honour—the sarcophagus of the great Duke of Wellington in St. Paul's Cathedral.

The next principal granite outcrop after Dartmoor is left, passing northward, is in the Charnwood Forest quarrying region of Leicestershire, where the stone approaches the syenite variety, but is so hard that it is almost entirely used for road-making, or for the curbstones of foot pavements in cities. Peaked hills at Mountsorrel and Markfield have been quarried away, and Bardon Hill, the highest in central England south of Derbyshire, is being strewn upon the macadamised roads far beyond the bounds of its enormous prospect, which includes the Malvern Hills, the Wrekin, and Lincoln Cathedral.

The next granite mass is reached on the eastern outskirts of the Lake District, at Shap, a brownish-red porphyrite variety largely used for ornamentation, and observable in London in the columns of St. Pancras Station, and also in the Temple Bar Memorial. There is further unworked granite on the western side of the Lake District. In Southern Scotland the granite of Kirkcudbrightshire is quarried for far distant transport, the Creetown and Dalbeattie varieties being used largely in architecture, as well as for commoner and more general purposes, such as road-making. It is, however, in the Aberdeen and Peterhead districts where the granite industry attains its greatest activity.

THE TRANSPORTATION FROM A CORNISH QUARRY OF THE 37-TON BLOCK OF GRANITE THAT FORMS PART OF THE BASE OF THE STATUE OF KING ALFRED AT WINCHESTER

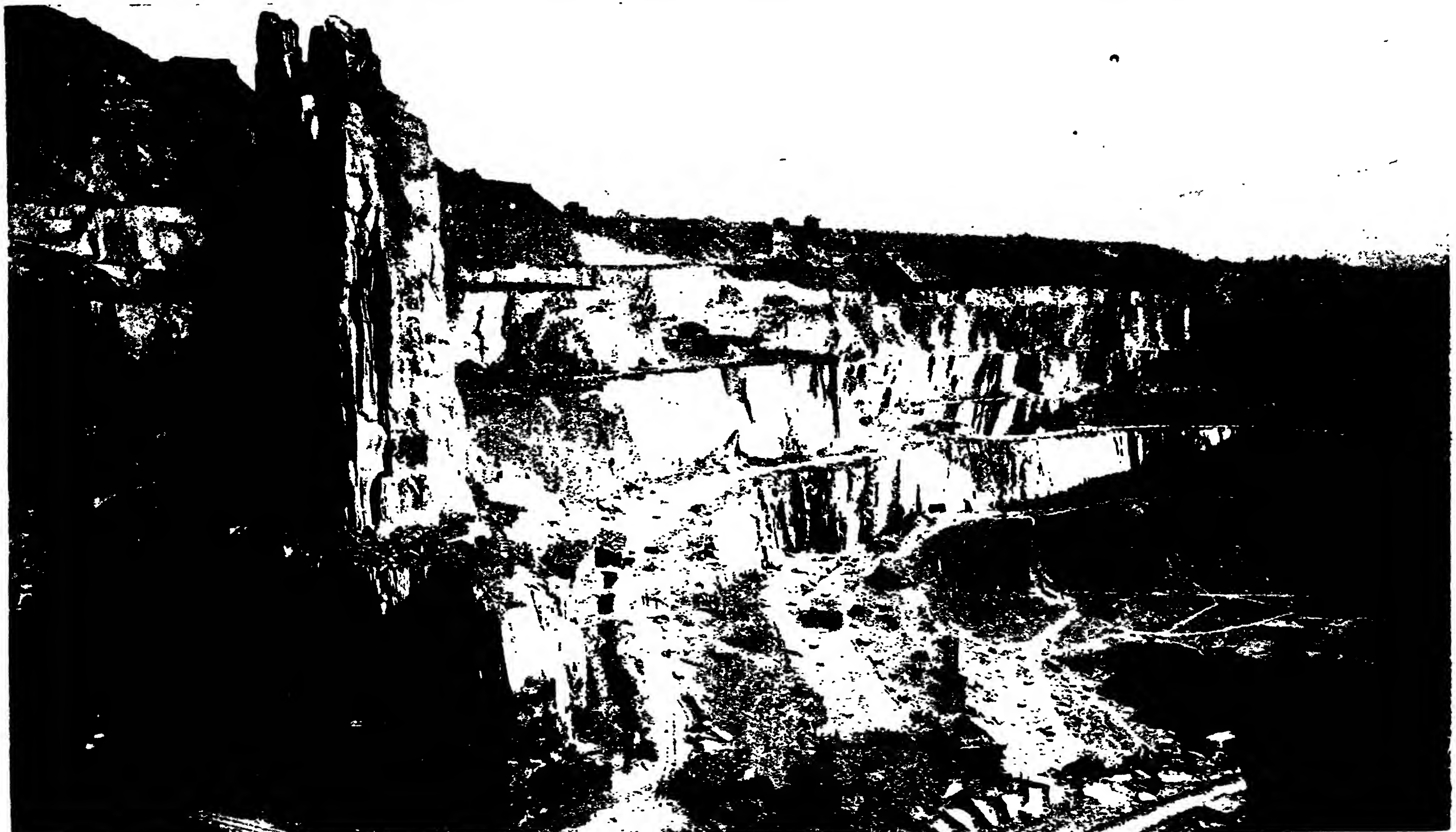
In the neighbourhood of Aberdeen alone, some nine thousand men are employed, quarrying the rock, and preparing it for the market. Here are some of the most renowned quarries in the world, such as Kemnay, Rubislaw, and Correnie. The latter furnishes a pinkish-red stone; the Kemnay a bright light grey—the characteristic Aberdeenshire colour—while the Rubislaw is of a darker colour, as may be seen in the balustrades of Waterloo Bridge. The Peterhead granite, often used in conjunction with Aberdeen, is from a dark flesh tint to red. It is used round the fountains in

QUARRYING THE GRANITES OF THE WEST

GENERAL VIEW OF THE WORK IN A CORNISH QUARRY

A RECORD BLAST AT A LARGE GRANITE QUARRY ON DARTMOOR

A WELSH MOUNTAIN WORKED FOR SLATE SIMULTANEOUSLY FROM BASE TO SUMMIT



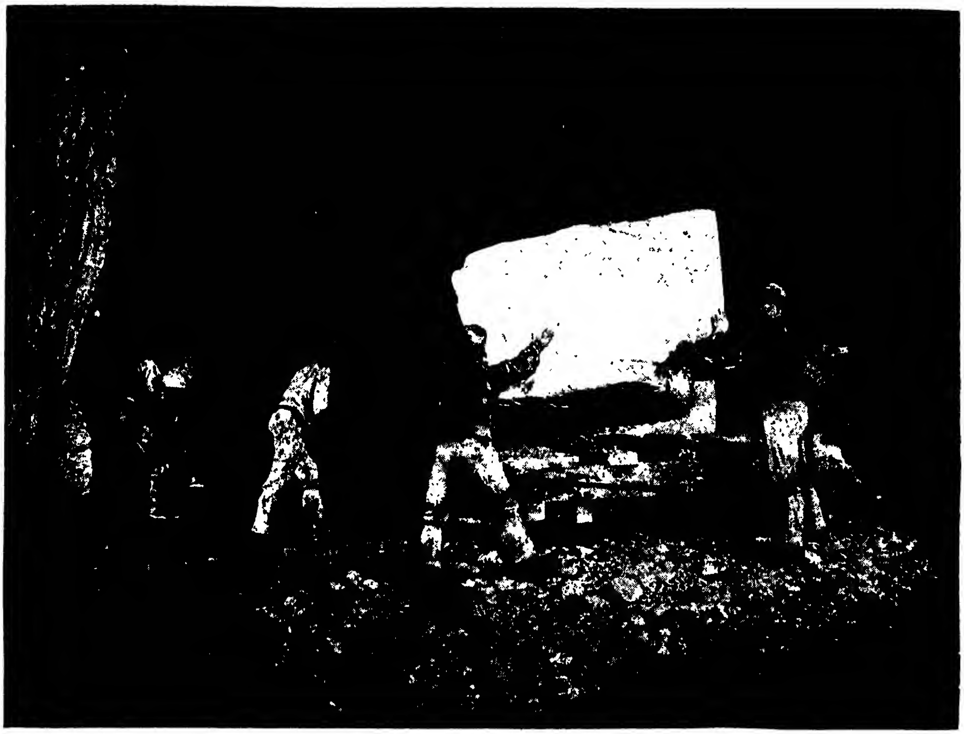
THE PENRHYN SLATE QUARRIES, AT BETHESDA, NEAR BANGOR. WITH THE NEIGHBOURING DINORWIC QUARRIES, THEY ARE THE MOST FAMOUS SLATE WORKINGS IN THE WORLD

Trafalgar Square. Some Peterhead granite—for example, from the Cairngall quarry—is grey, like Aberdeen.

The men who have been most closely identified with the development of the North Scottish granite industry are John Fyfe, who improved quarrying devices, and Alexander Macdonald, whose attention was given to dressing the stone and suiting it in size and adaptability for the market.

Granite is so tough that it must be blasted to detach it from the mass. Sometimes it is loosened in enormous quantities, by elaborately arranged blasting, so that tens of thousands of tons are at once made available for division into marketable blocks. It is sawn, not by a toothed saw, but by an untoothed steel bar, that cuts or abrades the rock by friction on minute steel filings; the groove, once begun, is

A MASS OF SLATE ROCK, 250 FEET HIGH AND WEIGHING 25,000 TONS, AND ON THE RIGHT A TRUCKLOAD OF GELIGNITE SLABS THAT WILL HELP TO LEVEL IT

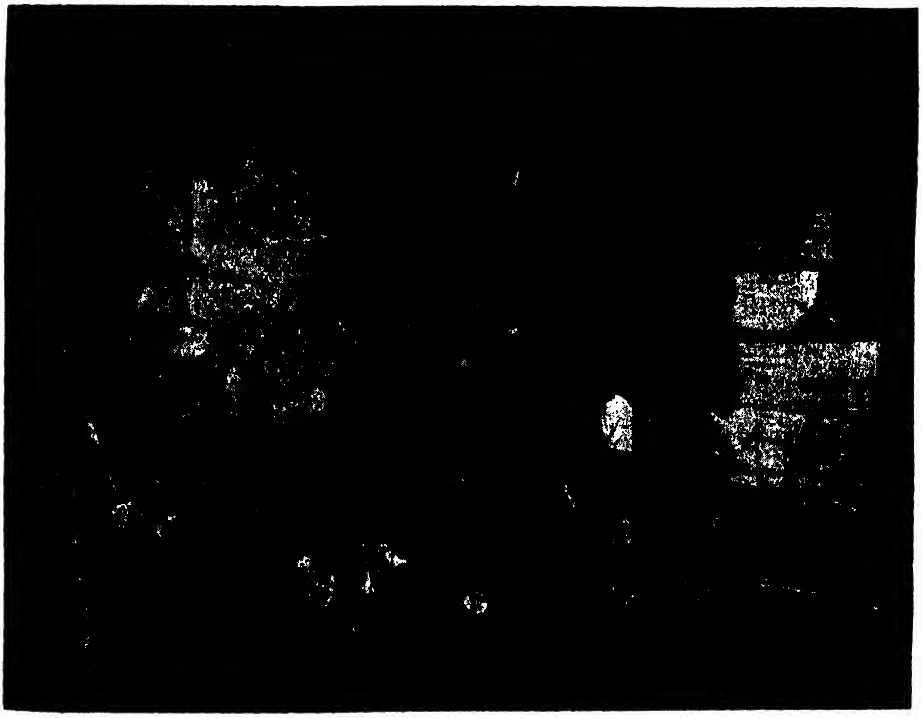


A CRANE LIFTING A BLOCK OF NAILSWORTH STONE IN AN UNDERGROUND WORKING

DRILLING BY HAND IN AN UNDERGROUND QUARRY AT NAILSWORTH

ENGLAND'S MOST NOTED BUILDING STONE

QUARRYING BATH STONE IN UNDERGROUND WORKINGS AT LONGSPLATT, SOMERSET



THE WORKING FACE OF A BATH STONE UNDERGROUND QUARRY AT LONGSPLATT

filled with water and with hard steel particles, which furnish the cutting surfaces as the bar is moved backwards and forwards in the gash by machinery. The dressing of granite is now chiefly done by chipping with chisels worked by pneumatic power.

DRILLING INTO THE FACE OF THE QUARRY PREPARATORY TO BLASTING

Granites are found throughout the western mountain districts of Scotland; in the Mourne Mountain region of Ireland: in Wicklow, Dublin County, Donegal, and Galway. The greatest importation is from Norway—known in the trade as "grey royal"—and both red and grey varieties are common in Sweden. The United States have many varieties, and France, Austria, and Germany are well supplied, while Egypt, as has been mentioned, has her historical syenite.

So far, we have only touched the quarrying where strength, durability, and a massive dignity are qualities of the stone won, or where the primal fire-welded cohesion of the rock is such that it will break up into lesser and lesser pieces, and still retain its power of resistance, thus making a solid, almost unwearable surface for roads, however small the breakages of the rock may be. But now we must turn to the more abundant and more easily worked rocks, that are available for familiar use, and take form under man's hand with less stubborn resistance.

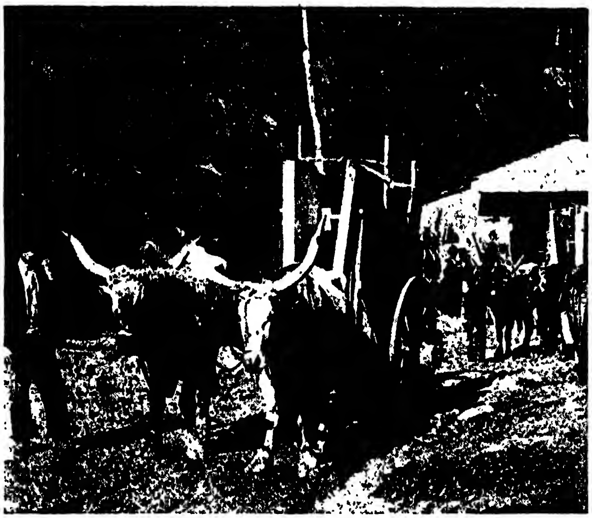
SPLITTING LARGE BLOCKS OF ABERDEEN GRANITE BY PNEUMATIC HAND-DRILLS

Because of the comparative ease in working them, the name of "freestone" has been given both to sandstones and limestones, though they are of very different formation, and here must be treated separately. Igneous rocks have been broken up in unnumbered years by weathering, and so carried away, their contents decomposed, and laid down in beds, in which quartz, particularly, remains intact in small particles. The grains, bound together by a strong cement that varies in composition. cover a considerable range of sizes, the larger-grained quartz remnants forming gritstone, and the smaller-grained sandstone. Often blocks of the original granite are found bound up with the granular mass, or pebbles and boulders are included In such cases the rock is called a conglomerate. Sandstones are quarried in many parts of the country, and make a valuable building stone. Gritstone is found in general in conjunction with coal measures, and is most largely worked in Derbyshire—which gives its name to the millstone grit—and in Lancashire and Yorkshire. The millstone grit is actually used, among other purposes, for the making of millstones, though their adoption for grinding corn is passing, or has passed, away. Among the best-known sandstones are the Forest of Dean, in the Old Red Sandstone measures, the "Red Wilderness" quarry, near Mitcheldean, being, perhaps, the best known. The millstone grit makes excellent paving for gradients that are too steep for the use of igneous rocks, as the grit is rough and affords a helpful foothold. On the other hand, it wears unevenly, weathering into

QUARRYMEN BRINGING THE BLOCKS OF MARBLE DOWN THE CARRARA MOUNTAINS ON SKIDWAYS SURROUNDED BY THE MARBLE REFUSE OF CENTURIES

hollows wherever wet collects. The most interesting of all the building stones, however, are unquestionably the limestones, with their metamorphosed form, the marbles. Limestones have been laid down in the sea, largely by an accumulation of shells and limed skeletons, such as is going on now at the bottom of every ocean. But the depositing of the material is only a first stage; decay, chemical action, crystallisation, pressure have followed, and in the case of marbles the influence in the neighbourhood of fire has been felt, causing complete crystallisation.

Innumerable limestones with a wide range of colour and quality are quarried from many geological formations, but the most attractive of all, unquestionably, are the Bath and Portland stones, from the Great Oolite series of rocks, and the marbles that are quarried to some extent in England and Ireland, but are to be seen in their most effective natural setting in Italy, at Carrara and Massa, inland of the little Mediterranean port of Avenza-Marina.



MARBLE SLABS LEAVING CARRARA

While stone-getting generally may be regarded as a rough and comparatively simple form of work—though much skill is needed in understanding the bedding and complicated lines of cleavage of such a rock as granite—it assumes a different character when the rock that is to be removed has the fine texture and appearance of Bath stone or the beauty of marble. The onlooker feels in their presence he is brought into touch with the true materials of art. In this connection the craftsman follows close on the heels of the labourer, and the artist follows the craftsman. It is when the easily manipulated building stones that are also beautiful in structure are reached that we begin to marvel how, from the ruins of the world's oldest crust, the skill of man creates the gorgeous palace and the solemn temple.

The beautiful white stone of the Bath district has been quarried from time immemorial, as anyone may know who visits the old baths left by the Romans; but few who have admired the stone in distant places are aware that it is quarried not only from the surface but from the interior of the earth, by processes that resemble mining much more than ordinary quarrying. A hasty glance through the neighbourhood might easily lead to mistakes, for the stone, after being brought to the surface, is left there for months to weather and harden, and so becomes greatly improved. The Portland stone, which is of very similar quality, is found at the surface, and is more easily worked in consequence. The features of Bath stone are its regularity of structure, which causes it to wear away evenly, its good appearance, and the comparative ease with which it can be worked.

A great impetus was given to the quarrying industry of the neighbourhood by the driving of the Box Tunnel on the Great Western line. The tunnel disclosed the presence of unsuspected stores of fine stone, and now there are more than sixty miles of underground workings in which anyone who did not know the plan of the roads followed would immediately get lost. The Bath stone of the kind that has gained a world-wide fame is generally found between thirty and forty yards below the surface, and the principal seams are from four to ten yards thick.

The method of working the stone, in what might not incorrectly be called the "mine," bears a general resemblance to the working of coal, except that there is no blasting, and the cutting of the seam begins at the top and not at the bottom. The rock being "holed" back, close to the roof, either by a compressed-air pick or as far as the workman can reach with his arms and pick, the block is cut downward with a saw at each end of the holed groove until a horizontal break in the stone is reached. The stone has now been separated from its surroundings

except on the face of the rock at the back, and it is broken off there by driving wedges into the natural niche at the bottom of the block and prising the wedges downwards, so as to force up the block, and snap its connection in the rear. The block thus separated is drawn out by a crane. The blocks so detached, varying in weight up to an occasional ten tons, are hauled by horses

RAW MATERIAL FOR THE SCULPTOR—BLOCKS OF MARBLE AT A CARRARA DÉPÔT

n trucks, as in a coal mine, to the bottom of shafts, up which they reach the surface or seasoning

The founder of the modern Bath stone ndustry was Ralph Allen, the original of Fielding's Squire Allworthy in "Tom Jones," and the greatest benefactor the 'Queen of the West" has ever known. This enterprising man, the son of a Cornish publican, arrived in Bath, at the age of eighteen, as a clerk in the Post Office. This was in 1711, and four years later he was useful in discovering local conspiracies connected with the Rebellion of 1715, and thus came into close association with General Wade, who then had the Bath command. Later, he was made postmaster, and married Wade's daughter. He organised a postal system in the West, and made much money as a contractor for the carrying out of his own plans.

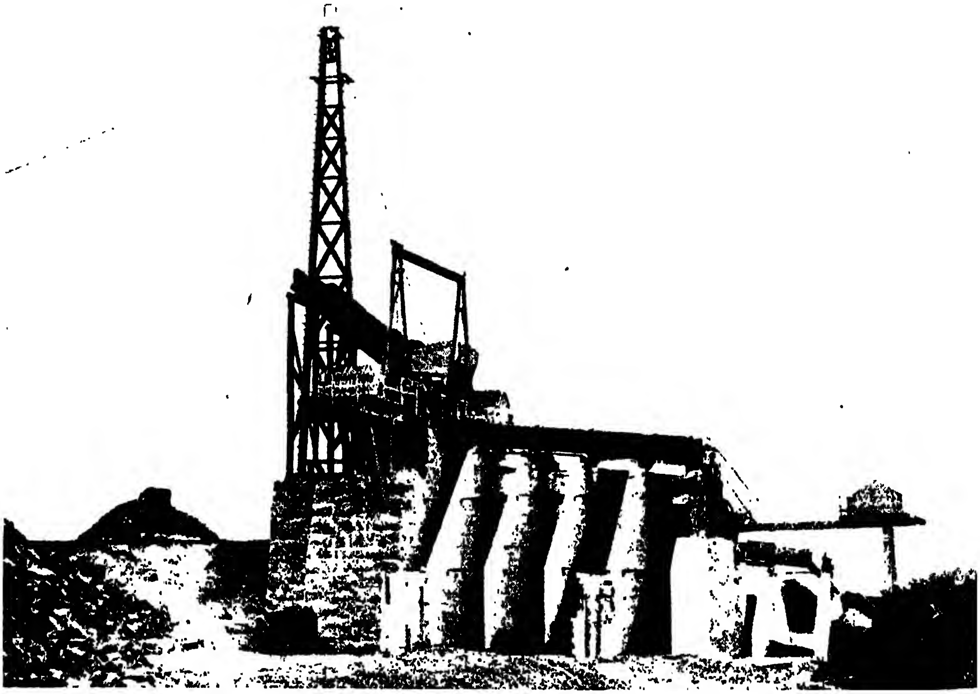
Bath had now grown into a fashion as a health resort, and Allen saw how the city might be improved and more wealth be gained by the development of the stone

trade, so he reopened quarries that had been abandoned, and later proceeded to build himself a mansion that would illustrate the value and handsomeness of the local stone. As a co-operative worker, he introduced John Wood, the architect, to whom the city owes its chief architectural attractions. In his later life Allen was an uncrowned king of the city. Bath remains the best advertisement of its own stone, and this is due chiefly to the initiative and energy of Allen, the postmaster, and the taste of Wood, the architect.

The quarrying of Portland stone is very largely carried on by Bath firms, as an adjunct to the Bath stone which it so largely resembles, each being composed to the extent of 95 per cent. of carbonate of lime. The Bath stone has a larger percentage of carbonate of magnesia than the Portland stone, and the latter is richer in silica. The product of the many quarries in the neighbourhood of Bath varies considerably in quality, in suitability for outdoor and indoor use, and in taking ornament securely. They give off moisture, and whiten and harden in the open air.

In any case, the power of resistance of the oolitic limestone under pressure—its bearing of tons weight per square foot before being crushed—is not high. Good Bath stone wi bear 200 tons per square foot, as again 500 tons for good sandstone, and 900 to for average granite. Sandstone is therefo generally used in the building of cities being both resistive and workable. Lond examples of the use of Bath stone may b seen in Apsley House and Buckingha Palace, while St. Paul's Cathedral is built c Portland stone.

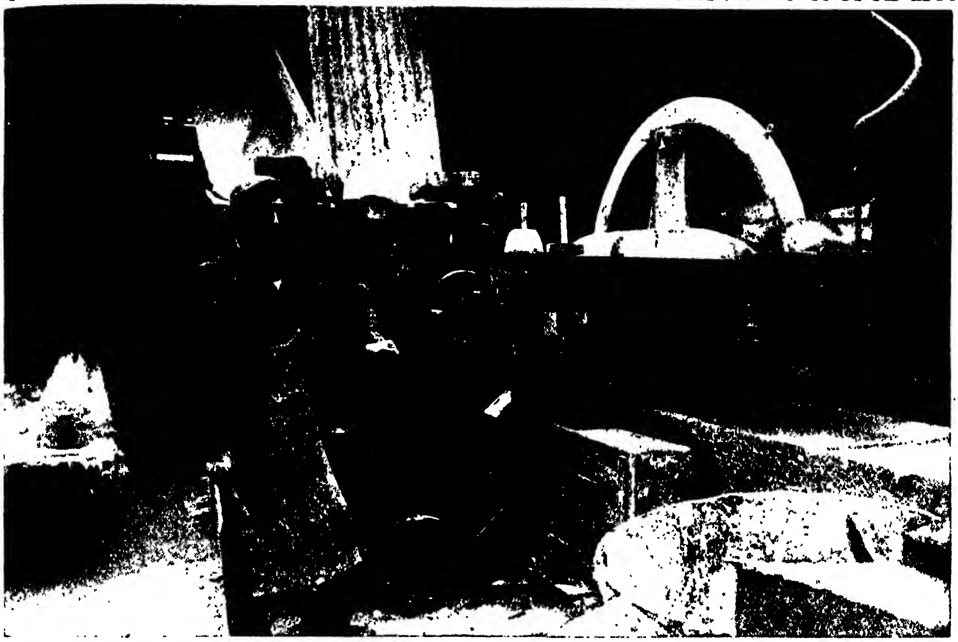
Besides the Bath and Portland ston there are great numbers of other ooli limestones used for building, as, for exampl Casterton stone, from near Stamford, used i the New Record Office, Fetter Lane, and i Ely Cathedral; Ketton stone, from ne Stamford, used in restorations of Pete borough, Ely, and York Cathedral Ancaster stone, from the neighbourhood Grantham, used in Lincoln Cathedral a Belvoir Castle; Haydor stone (Grantha to be seen in the great churches of Bost Grantham, and Newark; and menti should be made of the dolomite limestone Mansfield Woodhouse, of which the Hou of Parliament are built.



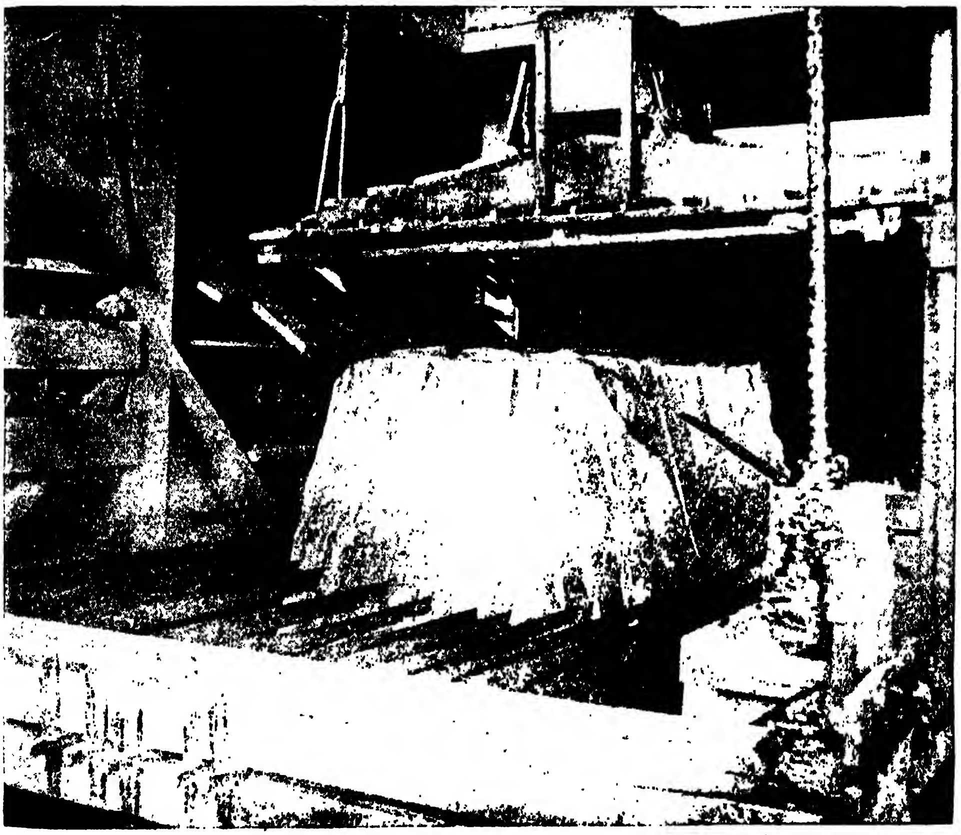
METAL FOR ROAD-MAKING CRUSHED AND GRADED BY MACHINERY

Marble, the purest form of limestone ar the most beautiful of all rock structures, i limestone that has been acted on by fi through the presence in its neighbourho

THE MACHINING OF GRANITE AND MARBLE



A DIAMOND CIRCULAR SAW CUTTING A BLOCK OF GRANITE



SAWING INTO TEN SLABS A TEN-TON BLOCK OF MARBLE

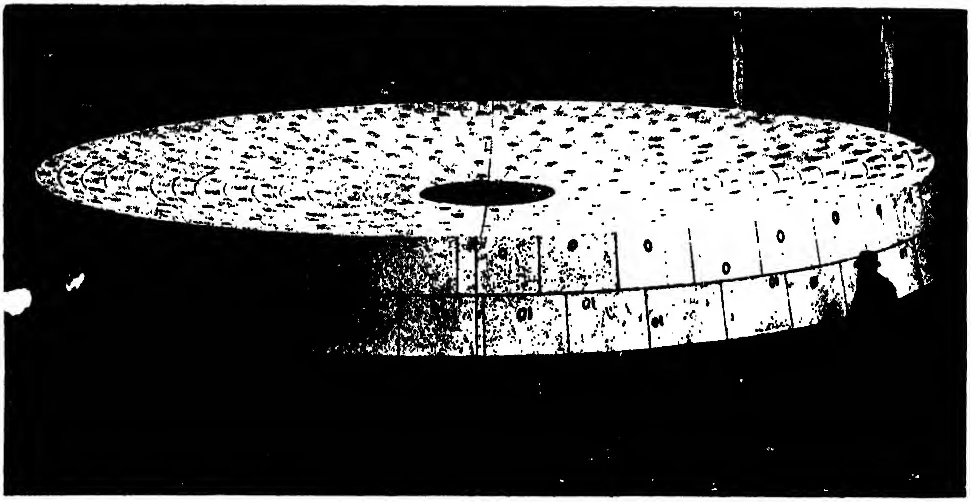
of the molten matter that forms igneous rock. The effect has been to render the limestone crystalline, with a beautiful, fine, granular appearance. The classical Parian marble and the marble of Carrara are white, but there are lovely coloured marbles —blood-red, green, yellow, and black. Some of these, exquisite in colour and texture, are found in Connemara.

Indeed, perhaps the easiest way of seeing a genuine marble-quarry within the British Islands is by ascending Lissoughter, the lowest and easiest of the Twelve Bens of Connemara, a peak that begins its rise from the garden of the Recess Hotel at Glendalough. On the shoulder of the Ben, a few hundred feet below the summit, is a quarry of beautiful stone, worked by methods that are not the less interesting because they are primitive. Slabs of marble that look naturally polished when water is thrown on the face of the rock are sawn from the face of the solid bed by an endless steel wire, which runs down the hill some half-mile or more before returning on its unceasing round. The object of having this taut, circular, cutting wire so long is, of course, that it may cool, after passing over the surface of the rock from which the huge slab is being sliced, before any part of the revolving wire returns again to saw through the groove that is being incessantly deepened.

Marble is used in this country—apart from statuary—almost entirely for decoration, for pillars, staircases, interiors, but in Italy, the land of marble, it is gloriously employed in whole buildings, as indeed it was in Greece. The Parthenon at Athens is built of marble from Mount Pentelicus. It was no vain boast of Augustus that he found Rome brick and left it marble—a transformation made possible by the comparative nearness of the Tuscan quarries of Carrara, quarries that from time immemorial have been available because of their proximity to the sea, the great shortener of distances.

The whole region around Carrara lives on marble today perhaps more than ever before. Travellers to Rome, somewhat short of half way between Spezia and Pisa, along the fringe of the blue Italian sea, note that the mountains which have long been jaggedly cutting the eastern sky have become scarred with yellowy patches, almost from base to summit. These are the four hundred quarries of Carrara and Massa; and when Avenza is reached the train is beset by brown-skinned Italians who would fain load the passengers with tile-like slabs of beautifully polished marble. Here a little to the right is the tiny port of Marina, to which the products of the distant quarries on the hills are sent down, for conveyance to all the world. In one way or another seven thousand men are working in these quarries or conveying their spoils to the lazy railway and lazier sea. Considerably more than half a million pounds' worth of the beautiful creamy stone is brought down here yearly, a value much increased before its destinations in all lands are reached.

The marble industry of Carrara is a



GRANITE BLOCKS FOR THE FOUNDATIONS OF THE VICTORIA MEMORIAL, CALCUTTA, FITTED INTO THEIR RESPECTIVE POSITIONS AND NUMBERED AT THE QUARRY SAWMILL

DISTRIBUTING THE STORES OF THE AGES

A THIRTY-TON CRANE USED IN LOADING BLOCKS OF MARBLE ON TO RAILWAY TRUCKS

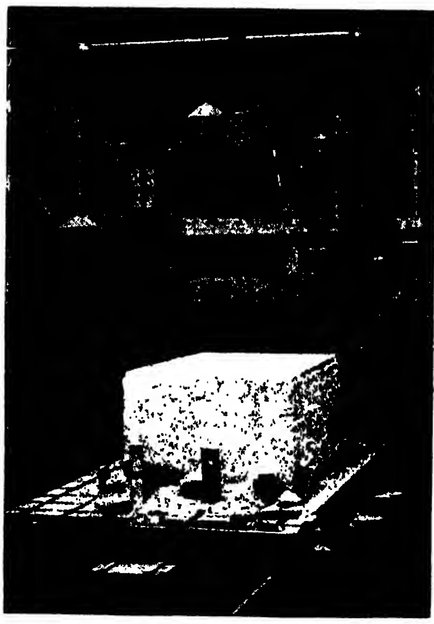
A TEAM OF TWELVE OXEN ON THE LOWER SLOPES OF THE CARRARA MOUNTAINS

rather elaborate example of division of labour. One set of men get the marble from its solid bed in the hills, and roughly square the blocks; another set let it carefully down the steep, scree-like slope of the hills, on wooden sledges, steadying the sledges with ropes passed round posts by the side of the rough track; and then, at the bottom of the slope, the blocks are loaded by a third set on to ox-trucks, powerfully braked, and so are slowly taken, with much abuse of the imperturbable oxen, to the railway and the sea, ten or a dozen miles away from the upper quarries.

TURNING A LARGE COLUMN OF CORNISH GRANITE

The marble is quarried by blasting with dynamite, a high degree of skill having been reached in so arranging the shots as not to break up the stone unnecessarily. The marble so procured is the raw material for a perfect hive of more or less artistic workers in the towns below. Practically all great sculpture from the time of Michael Angelo has been chiselled from stone brought down from these inexhaustible quarries. It is only by seeing quarries like those of Carrara that anyone can realise how cathedrals like Milan could be built.

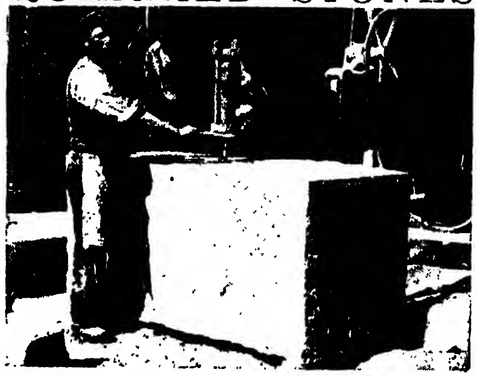
One of the most important, though not the most widely spread, forms of quarrying is the getting of slates for roofing and for school use. Slate is a rock that has been metamorphosed or changed by compression, and by stresses on the earth's crust, and both sedimentary and igneous rocks are affected. The special quality of slate that gives it its usefulness is its ready cleavage combined with hardness. Slate quarries are not worked over a wide area. The best known are the Dinorwic and Penrhyn workings, near Bethesda, in North Wales. Here practically the whole range of slaty rocks is exposed and attacked at once, the Dinorwic quarry having a face 1800 feet deep, worked in separate galleries, or steps, of 75 feet each. In the Blænau Festiniog quarries, further south, the best slates are got not from open workings but from mines. In the Lake District workable slate is found on Skiddaw, and the Honister quarry at the head of Borrowdale is known to every visitor. Cornwall has one fine quarry, the Old Delabole, producing excellent roofing slate that has been extensively used on Government buildings, such as the New Patent Office and the South Kensington Museums; and the West of Scotland roofs Glasgow and other towns.



A PLANING-MACHINE AT WORK ON A PORTLAND STONE CORNICE

This glance over a scattered but enormous industry, including obstinate granite, tenacious sandstone, limestone beds that lend themselves to some degree of artistry, homely slate, and the splendid possibilities of marble, has disclosed to us how man seeks strength for his architecture from the oldest formations that have been nearest to earth's central fires—the granites and syenites and basalts—but attains greater adaptability when he is manipulating the rocks which have been re-formed, perhaps again and again, by the earth's later changes. His materials of beauty are comparatively of yesterday, but he finds power in the oldest; and it is the aged that endures.

THE SHAPING OF QUARRIED STONES

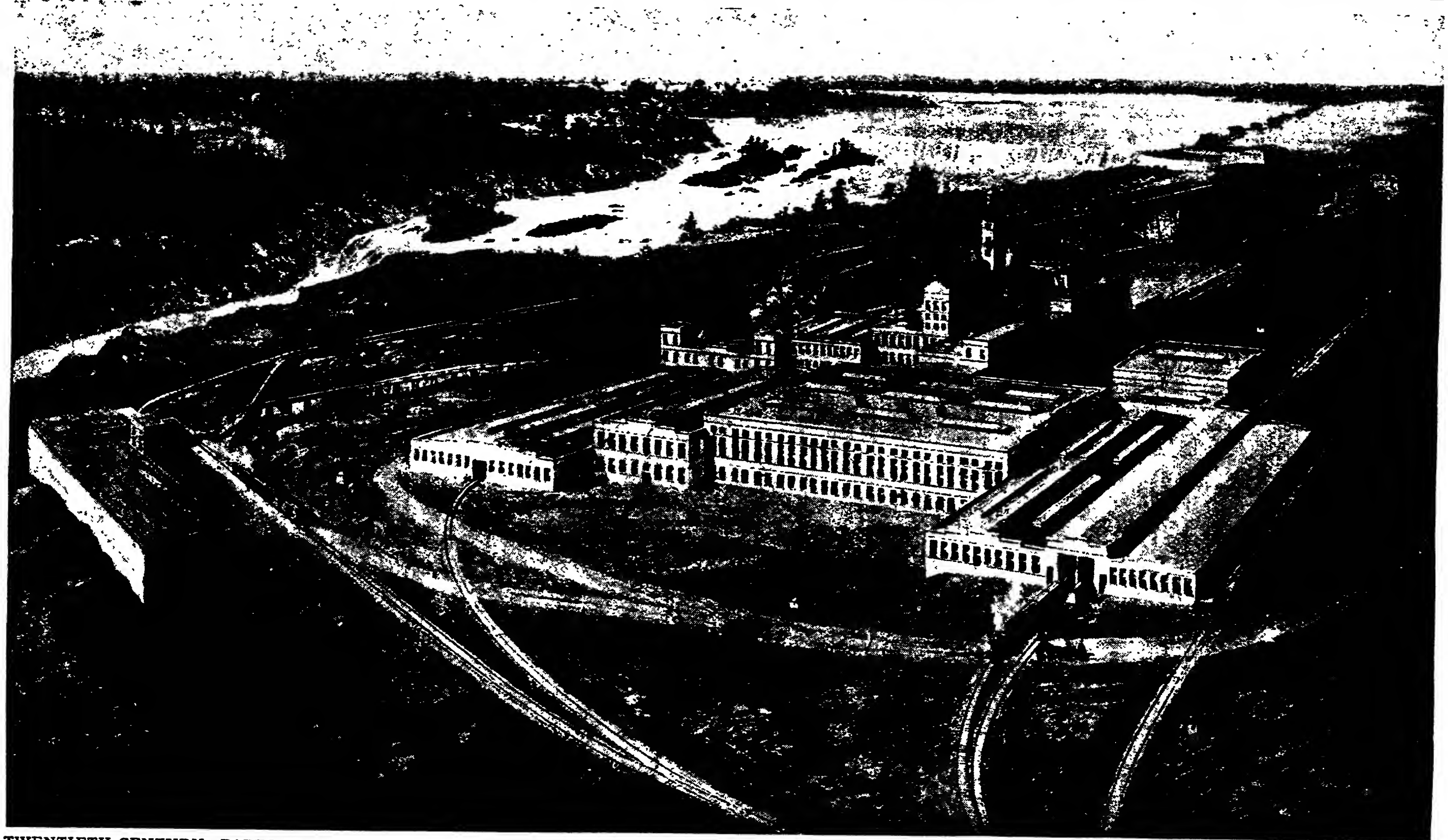



DRESSING GRANITE BLOCKS WITH HAMMER AND CHISEL AND PNEUMATIC TOOL

MASONS AT WORK ON THE ST. ALDHELM BOX GROUND STONE AT BOX, SOMERSET


MOULDING MARBLE CAPITALS WITH MALLET AND CHISEL AND PNEUMATIC TOOL

A MANUFACTURE BEST ESTABLISHED NEAR THE SOURCE OF ITS RAW MATERIAL



TWENTIETH-CENTURY PAPER-MILLS BUILT BESIDE GRAND FALLS, NEWFOUNDLAND, WITH FOREST, WATERWAY, AND WATER-POWER HARD BY

MANUFACTURED EXPORTS

Our Commerce in Miscellaneous Manufactures, from Chemicals to Toys

ART AND SCIENCE IN MANUFACTURE

In the last chapter we reviewed the major part of our commerce, which we saw to be concerned with metals and textiles. The remainder of our trade of this kind is smaller by comparison, but of great importance, and is, in some cases, concerned with articles which we import on a considerable scale. As to metals and metal goods, we saw that our exports of British make are about two and a half times as great as our net imports for home consumption. As to textiles -yarns and fabrics, and ready-made clothes—our exports of British make are between four and five times as great as our net imports. Coming to the remainder of our commerce, and treating it as a group of miscellaneous goods, we find that our exports of British make are only about 20 per cent. greater than our imports.

The consideration in some detail of these miscellaneous manufactures makes a deeply interesting study, of profound significance to our national welfare. All sorts of useful and ornamental articles come under review. There are the many products, some crude and some finely finished, which come under the general heading of "Chemicals." There is the great variety of products which are grouped under "Leather and leather goods," varying from undressed skins to fashionable boots and gloves. There are the useful and sometimes artistic products of the potter's skill, and the sometimes cheap and sometimes very costly articles made of glass. The growth of enormous reading publics in modern civilisations has made the trade in paper of very large dimensions. Trade in manufactures of wood and furniture is comparatively limited. Then there are the minor but nevertheless important trades in indiarubber goods, cement, musical instruments, soap, and so forth. The general dimensions of the entire group of miscellaneous trades, and of some of the chief of them, are shown in the statement appended.

COMMERCE IN MISCELLANEOUS MANUFACTURES—1910

Manufacture	Imports		British-Made Exports
	Gross	Net, after Deducting Imports Re-exported	
	£	£	£
Chemicals, drugs, etc.	11,260,000	9,321,000	18,568,000
Leather and leather goods.. ..	11,825,000	9,608,000	4,686,000
Leather boots and shoes ..	674,000	632,000	3,030,000
Earthenware and glass ..	3,817,000	3,611,000	4,352,000
Paper	6,414,000	6,182,000	3,123,000
Wooden goods	2,338,000	2,091,000	1,836,000
Miscellaneous	23,700,000	20,900,000	31,000,000
Total ..	£60,028,000	£52,345,000	£66,595,000

Taking the group as a whole, the net imports in 1910 were worth just over £52,000,000, while the exports of British make were worth nearly £67,000,000. These figures at once suggest that in many of the trades concerned there is an extensive foreign competition in the home market, and the nature and character of this will appear as we proceed.

The fact that one manufacturing industry is often a maker of the raw materials of another plays a large parts in the commerce summarised above. It should never be forgotten that trade is a matter of mutual benefit. We have already noticed how true that is in the case of machinery, in which we see one nation furnishing another with the primary means of doing work. The same consideration applies in no

small degree to our trade in miscellaneous manufactures. It ought to be obvious that nation A can only export to nation B articles which are useful to or desired by the citizens of nation B, but it is not difficult to lose sight of this elementary consideration in connection with the meaning of the commercial statistics which represent the exchanges between nations.

The first item in our statement, Chemicals, represents fully as much as in the case of machinery the supply by one nation to another of the means of doing work. The great bulk of the trade in commercial chemicals is for the purposes of manufacturing industry; and it would be as proper to classify the articles of which it consists under "Raw Materials" as under "Manufactures." Indeed, even when chemicals are bought retail, as in the cases of soda and "blue" for household purposes, the manufactured stuff is usually bought by the housewife as the raw material of domestic industry.

The Board of Trade use, for the trade returns, the general classification "chemicals, drugs, dyes, and colours," and a very large number of widely varying substances are thus grouped, including bleach, alkali, coal products, such as aniline and alizarine dyes, benzol, naphtha, tar, carbolic acid, and pitch, sulphate of copper, natural dyes, glycerine, chemical manures, sulphate of ammonia, basic slag, drugs, painters' colours, sulphuric acid, and tartaric acid. It is to this large group that the following statement refers.

BRITISH COMMERCE IN CHEMICALS, DRUGS, DYES, AND COLOURS

Year	Net Imports for Home Use	British Exports
	£	£
1900 ..	6,625,000	11,343,000
1907 ..	9,915,000	17,053,000
1910 ..	9,321,000	18,586,000
1911 ..	9,985,000	20,055,000

The great increase in commerce of this kind in the last eleven years is altogether satisfactory, in view of the nature of the important materials of industry with which it is chiefly concerned. So far from there being need to regard the greater part of our imports of manufactures of this kind as competitive, we need to regard them as supplies in aid. The growth of imports is a proof that the industries which need them are also growing. It is no less true that the growth of our exports of chemicals would not have occurred unless foreign industries had been growing and calling for more material. The gross imports of 1910, worth £11,260,000, were made up as follows: crude chemicals (chiefly borax, brimstone, bleach, cream of tartar, glycerine, coal products, salt, saltpetre, soda compounds, and tartaric acid), £3,900,000; drugs and medicines, £1,200,000; dyestuffs, natural and artificial, and ta ning substances, £4,000,000; painters' colours and pigments, £1,600,000; other articles, £600,000. It is not too much to say that any diminution of these figures would mean a decline in British industry, and we may therefore congratulate ourselves that they show healthy increase in the last ten years.

Turning to the exports of chemicals, the exports in the last few years were thus composed.

ANALYSIS OF OUR CHEMICAL EXPORTS

Products	1910	1911
	£	£
Bleach	211,000	195,000
Coal products (chiefly pitch, tar, carbolic acid, and benzol) ..	1,679,000	1,883,000
Copper sulphate ..	783,000	1,509,000
Dyestuffs	337,000	302,000
Glycerine	653,000	773,000
Manures (chiefly sulphate of ammonia) ..	4,922,000	5,496,000
Medicines	1,875,000	2,013,000
Muriate of ammonia ..	171,000	187,000
Paints and colours ..	2,693,000	2,829,000
Soda compounds ..	1,875,000	1,864,000
Total above and other chemicals	£18,600,000	£20,100,000

It should not go without notice that whereas we export only about £200,000 of dyestuffs in a year, we import about £2,000,000 worth. The reason for this is of much importance. One country, Germany, has gained a virtual monopoly of the coal-tar dye industry, and has become the almost universal colouring agent of the modern world.

The first practical aniline dye was produced by the late Sir William Perkin, who, continuing the researches begun by the German chemist Runge, produced a practical aniline dye in 1856, and the British dyeing firm of Pullar was, we believe, the first to employ it. The work of Perkin was not developed here at all, and the chance to establish a great new branch of the chemical industry was resigned to the Germans. The German chemists were not content to produce the beautiful but fugitive colours derived from aniline—a

hydro-carbon derived from benzine. They went further, and, working upon other hydro-carbons derived from coal-tar, gave us permanent coal-tar dyes. Alizarine is the essential colouring matter of madder, and until forty years ago the madder root was the only source of this valuable substance. In 1868, however, Graebe and Liebermann produced alizarine artificially from anthracene. Later, German chemists succeeded in producing artificial indigo, and with such success that they have beaten the natural product. Here is the remarkable contrast between our imports and exports of coal-tar dyes.

BRITISH COMMERCE IN COAL TAR DYES—1910

Dyes	Imports	Exports
	£	£
Aniline dyes ..	1,453,000	Not separately stated
Alizarine dyes ..	283,000	,,
Artificial indigo ..	101,000	,,
Other coal-tar dyes ..	1,000	,,
Total ..	£1,838,000	£190,000

That is surely a very striking comparison; and it speaks volumes for the assiduity with which the Germans have devoted themselves to what may be called scientific as distinguished from rule-of-thumb industry. It is impossible not to admit that the Germans have deserved their success in this branch of effort. The coal-tar dye industry, indeed, is an object-lesson we shall all do well to take to heart. The production of the lovely colours which now emanate from German laboratories is a triumph for the German industrial chemist, and it is typical of the methods that have enforced German progress in the last generation. The world has reached a degree of development calling for such attainment as a matter of course.

In the production of alkali, on the other hand, British makers are exceedingly successful. Our exports are worth about £2,000,000 a year, and our imports are negligible. This success is due to the energy with which certain British capitalists have exploited the scientific discoveries of France and Germany.

We turn next to leather. Our commerce in leather is very large, as might be imagined from the importance and variety of the trades which use it as a material. Taking that part of the figures in the table on page 2797 relating to leather as distinguished from leather goods, we find that our trade in recent years has been as shown in the following table.

BRITISH COMMERCE IN LEATHER

Year	Imports for Home Use	British Exports
	£	£
1900 ..	7,195,000	1,130,000
1907 ..	7,208,000	2,032,000
1910 ..	7,769,000	2,815,000
1911 ..	7,970,000	2,887,000

This statement relates to many varieties of leather, used for many different purposes. It covers undressed and dressed hides, and tanned or dressed goats' skins and sheeps' skins—products used as materials by boot and shoe makers, bag and trunk makers, harness and saddlery makers, machine-belting manufacturers, upholsterers, bookbinders, fancy goods makers, the textile trades, and other industries too numerous to mention. In fact, there are very few trades which do not use leather in some form. Here again, then, the imports may be regarded not so much as competitive as supplying invaluable materials for manufacturers.

The commerce in gloves is of surprising dimensions. The net importation of gloves for home consumption is worth about £1,250,000, and the average import price is about 21s. per dozen pairs. Exports of gloves, on the other hand, are worth little more than £300,000 a year. This is one of the minor trades in which there is a good deal of foreign competition. As to saddlery and harness, we have no recorded imports, and our exports are worth about £500,000 a year. The industry has suffered badly through the motor-car.

The most important of the leather goods trades is that in boots and shoes, and here British makers more than hold their own. The figures are as follow.

BRITISH COMMERCE IN LEATHER BOOTS AND SHOES

Year	Imports	Exports
	£	£
1900 ..	645,000	1,479,000
1907 ..	728,000	2,041,000
1910 ..	632,000	3,030,000
1911 ..	627,000	3,355,000

These facts speak of what is nothing short of a triumph for the British boot and shoe industry, and it is a triumph the more remarkable because at the first date with which the above table deals—the year 1900

—it appeared that our exports of this kind were declining, while foreign competition in the home market was increasing. If we go back to the year 1890, we find that our exports of leather boots and shoes had reached nearly £1,900,000, while our imports of the same kind were worth about £300,000. Ten years later exports had fallen, while imports had increased. Since then a great change has come over the trade. We see that exports have much more than doubled in the eleven years, while imports, after rising a little, have fallen. In 1911 the exports of British boots were more than five times as great as our imports of foreign boots.

These facts are a great encouragement to those who hold the view, often expressed in these pages, that, while it is true that foreign competition in oversea commerce must be expected to increase, the markets of the world are at the same time expanding so rapidly that there is no reason why British exports should not further expand. The above healthy increase in the British exportation of boots has been made, let it be remembered, in a world where boot-machinery and boot-factories have been springing up everywhere, so that competition in bootmaking must have been growing. It is clear that the market for boots has nevertheless grown so rapidly that British makers have been able in a decade to carry their sales to unprecedented dimensions.

The case of this trade is particularly interesting. It is one in which there has been a revolution in the last fifteen years or so. The great bulk of the boots that are worn by the general public are now made by specialised machinery which originated in the United States of America. Fortunately for British industry, it was wise enough to adopt and adapt the new method, and to submit to the process of change. If it had not, it would have gone to the wall. Keeping itself abreast of the time, and drawing freely upon the best materials and the best plant offering in the world, it secured the larger exports we have examined, and it sustained the workers in the trade. If the exports had not been secured, there would have been great suffering in the boot centres, because of the saving of labour brought about by the new system of working. Each part of a boot is now executed by a separate and specialised machine, which performs its work with incredible rapidity. Consequently, boot-making does not call for nearly as much labour as of old; and it is obvious, therefore, that if exports had not happily increased large numbers of men would have been thrown out of employment. Here we have considerations applying in some measure to many different industries, and in all of them the means of success can only be those which have availed in the boot and shoe industry.

Turning to our trade in earthenware and glass, we see by the table on page 2797 that, grouping them together, exports are rather larger, but not much larger, than net imports for home consumption. Taking earthenware alone, exports are much larger than imports.

BRITISH COMMERCE IN EARTHENWARE.

Year	Net Imports for Home Use	British Exports
	£	£
1900 ..	777,000	2,038,000
1907 ..	880,000	2,649,000
1910 ..	740,000	2,780,000
1911 ..	858,000	3,029,000

In the eleven years imports have increased about 10 per cent., while British exports have increased by about 50 per cent. This is excellent, especially as 1900 was a good year of trade. It is necessary, however, to note that the term earthenware covers a very great variety of articles, and

PRODUCTION AND TRADE IN EARTHENWARE—1907

Class of Earthenware	Production	Exports (British) 1907	Net Imports for Home Use
	£	£	£
Porcelain and chinaware	1,025,000	195,000	175,000
Sanitary ware, earthenware tiles, and other earthenware	5,091,000	1,979,000	657,000
Jet, Rockingham, and glazed terra-cotta ware	175,000	3,000	—
Red pottery, stoneware, brown and yellow ware	842,000	291,000	15,000
Electrical ware, door fittings, crucibles, etc.	636,000	181,000	33,000
Total	£8,104,000	£2,649,000	£880,000

success in them is by no means even. In 1907 the Board of Trade made a Census of Production; and in their report, dated 1910, they take opportunity to compare imports and exports with production in such parts of the trade as is possible. The result is as given on page 2800.

In the light of this analysis we see where our strength in exportation lies. It will be seen that the greater part of our export figures is accounted for by sales of earthenware, and that importation is also chiefly under this head. In porcelain and china there is little either of importation or exportation This is undoubtedly another industry in which a vast amount of expansion is possible; and the experience of the last ten years leads us to hope that those engaged in it will not fail to play their part in the world's widening markets.

In the allied glass trades the records are of very great interest, and here we find the imports considerably larger than the exports. They are as these figures show.

BRITISH COMMERCE IN GLASS

Year	Net Imports for Home Use	British Exports
	£	£
1900 ..	2,488,000	1,033,000
1907 ..	2,972,000	1,400,000
1910 ..	2,866,000	1,572,000
1911 ..	2,988,000	1,684,000

In 1911 imports were nearly twice as large as exports. In 1900 there was an even greater disparity, for imports were then nearly two and a half times as great as the exports of British make. The considerable size of the imports for such a small industry is accentuated by the fact that the Census of Production, taken in 1907 (when, it will be seen, our net imports of glass for home consumption amounted to as much as £2,972,000), showed that the factory value of the output of glass and glassware in British factories in that year was only £4,858,000. It is clear, therefore, that a very considerable part of the British home market is enjoyed by foreign glass manufacturers, for in 1907 we exported £1,400,000 worth of the home product. In 1907 we consumed at home £3,458,000 worth of our own glass, and, in addition, imported for home use £2,972,000 worth of foreign glass.

The fact is that, in the production of ordinary glass for domestic consumption, the lead has been taken by Continental manufacturers. Not only Germany, but Austria-Hungary, Belgium and France are ahead of us in this industry. Both Austria and Belgium export nearly twice as much glass as we do, while Germany is even further ahead. In the year 1910, when the United Kingdom exported £1,572,000 worth of glass; Germany exported nearly £5,000,000 worth.

It appears that this is an industry in which the British trade as a whole—not by any means in every section—has allowed itself to fall behind in technique. This evidently was brought home to the trade a few years ago, for we find that in 1902 the Technical Instruction Committee of the Staffordshire County Council sent a qualified investigator to visit the Continent and report upon the methods used in the modern glass factories. Mr. Frederick Carder, who undertook this important duty, made a very illuminating report, which shows how much he was impressed by the glass manufacturers who make the bulk of the world's glass. The result of his investigations may be summed up by saying, at every point he concluded that advantage and economy of method was with the Continental manufacturer. We find him commenting upon the contrast between " the vile smoke, the insufferable temperature, and the still worse effects of sulphur " of the average British glass-house, and the " quite bearable " conditions under which the average German glassworkers labour.

As to economy, Mr. Carder has something to say on the important matter of the furnaces used at home and abroad. The Germans, it appears, and the Austrians, almost universally discarded the methods we employ. " Take, for instance, the regenerative gas-furnace of Frederick Siemens, which not only permits the attaining of temperature quite inaccessible in the old style of furnace still used in England, but also lends itself to the use of a very poor fuel, such as a low-class lignite or brown coal. This furnace made it possible to introduce the glass industry as remunerative occupation for the people in districts where it had not previously been able to exist. In Austria, out of 176 firms manufacturing all kinds of glass, there are 157 furnaces worked by gas systems, and only 65 furnaces with the direct firing of either coal or wood, which is invariably used in England. In Germany, out of 341 firms, there are 603 furnaces worked by gas, and only 94 furnaces with direct firing."

And to this the report adds: " In all the British houses making table-glass today, not

one is using gas-furnaces; they are working the same old style of furnace that has been in use for the past hundred years." On another point of method we find the investigator saying of a factory near Cologne: "A machine was in use for melting the tops of wine-glasses, tumblers, etc., at the rate of 3000 an hour. What English factory could work at one-third the rate?"

What seems to be needed in this industry is that adaptation of successful foreign methods which has done so much for the boot and shoe trade. Nothing is more certain than that the chemist and engineer, properly employed in the glass industry, could greatly enlarge British production both for the home and export markets.

In turning to our trade in paper, we pass to a very different order of industry. The greater part of the paper used nowadays is of a poor description, necessarily made out of the cheapest available materials, chiefly wood-pulp, and produced with great facility and little labour. The dimensions of our commerce in paper are as follow.

BRITISH COMMERCE IN PAPER

Year	Imports for Home Use	British Exports
	£	£
1900 ..	6,222,000	1,649,000
1907 ..	5,527,000	2,344,000
1910 ..	6,182,000	3,123,000
1911 ..	6,365,000	3,312,000

To understand how large is the use of paper in the United Kingdom we have, in addition, to turn to the Census of Production report. This shows that in 1907 the total output of the British paper trade—factory value—was about £13,000,000. Of this, as will be seen by the above table, we exported £2,344,000, leaving £10,600,000 worth of British paper for home use. In addition, we imported £5,500,000 of foreign and Colonial paper for home use; and in 1907, therefore, we actually consumed over £16,000,000 worth of paper, or about forty shillings' worth for each family in the country. This allowance, generous as it is, has since been exceeded.

It is perhaps not surprising that imports in this trade exceed exports. It is obviously convenient to erect paper-mills where the timber is grown, and to export from timber areas not wood-pulp but finished paper. Nevertheless, it will be seen that our exports of British paper have doubled since 1907; and it is almost certain that the next Census of Production report will show that the value of the make of British paper has increased considerably since 1907.

The next item in the table on page 2797—viz., wooden goods—covers not only joinery and turnery but furniture. Imports and exports of the group as a whole are very nearly equal in value. As to furniture, commerce is of comparatively small dimensions, probably owing to the fact that local taste is best satisfied by local production. Trade in 1900–1911 has shown these figures.

BRITISH COMMERCE IN FURNITURE

Year	Imports for Home Use	British Exports
	£	£
1900 ..	Not Known	637,000
1907 ..	543,000	802,000
1910 ..	373,000	987,000
1911 ..	380,000	1,280,000

Imports are small and not progressing. Exports of British furniture are larger, and are beginning to assume considerable dimensions. It is a notable fact that our exports under this head doubled in the eleven years 1900–1911. British cabinetmakers are, of course, chiefly concerned with supplying the home market. The Census of Production shows that in 1907 the output of furniture, house furnishings, and upholstery was worth, at factory prices, about £18,000,000, and at the present time this figure is probably greatly exceeded. With a growing home market and a widening opportunity abroad, there seems to be an excellent opportunity for expansion before this trade.

The imports of joiners' work are, contrary to a widely held opinion, almost negligible. The official returns show that our imports for home consumption of house-frames, fittings, and joiners' work were in 1909 £181,000, in 1910 £203,000, and in 1911 only £176,000 in value. It is obvious that these tiny figures represent no more than a quite insignificant fraction of the value of the joinery annually made in the United Kingdom in connection with the building of houses. Of wood ware and wood turnery the imports are larger, reaching about £1,700,000 in 1911; imports of this kind also appear to be increasing.

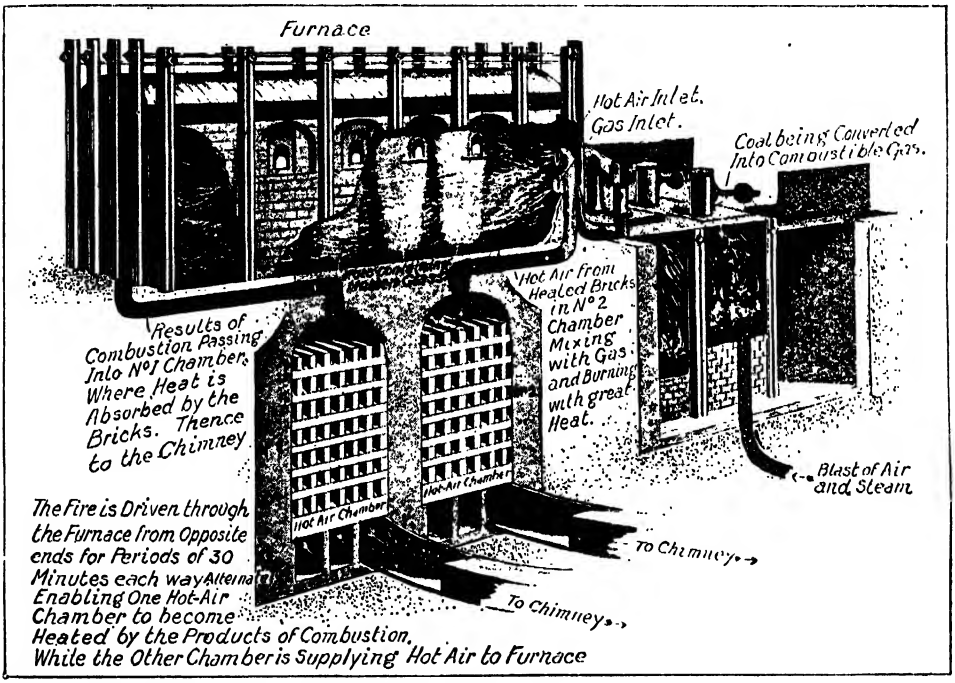
Some of the minor trades contributing to the figures under "Miscellaneous" in the table on page 2797 deserve our attention. The cement trade is one which the home market is almost entirely supplied by British firms, who act in combination. The imports are falling, as will be gathered from the statement which follows.

BRITISH COMMERCE IN CEMENT

Year	Imports for Home Use	British Exports
	£	£
1900 ..	200,000	673,000
1907 ..	147,000	1,207,000
1910 ..	77,000	1,062,000
1911 ..	95,000	1,075,000.

There is now very little foreign competition in the home market, but it is not a little difficult to increase exports, for freights are an obstacle with a material of such character. The importance of the Custom House in the Board of Trade Returns.

There is undoubtedly a prospect of enormous future growth before the rubber industry, if it can secure plentiful and cheap supplies of material. We saw, in considering the prices of recent years, how great an advance there has been in the price of rubber. Happily, there is every prospect of cheap supplies in the future. Not only can unlimited natural supplies be secured by planting in the wide areas of the world where rubber can be grown, but we have also the promise of artificial rubber.



THE SIEMENS REGENERATIVE GAS-FURNACE USED IN UP-TO-DATE GLASS-MAKING

In this modern furnace there is no smoke, no soot, and but little waste heat. Coal burnt with a blast of steam and air is converted into combustible gas, which is burnt in the furnace mixed with air that has been heated by the results of the previous combustion.

cement manufacture has greatly increased of late, because of its extended use in concrete construction in the building trades.

The rubber manufacture has had a mushroom growth. It is difficult to say what the total dimensions of our external trade of this kind really are, since rubber enters into apparel, footwear, tyres and tubes for carriages, motor-cars, motor-cycles, and cycles, and its records are therefore commingled with those of other trades. Of rubber manufactures separately distinguished, however, we had in 1910 and 1911 an exportation worth over £1,800,000. The imports are small, and not separately recorded by the

Professor W. H. Perkin, of Manchester University, a son of the late Sir William Perkin, who first made a practical aniline dye, read, on June 18, 1912, to the Society of Chemical Industry, an important paper on the discovery of a method of producing synthetic rubber on a commercial basis. He said there was the possibility of production at a cost of a shilling a pound, or less. The fortunate discoverer of the process is Dr. F. E. Matthews, who apparently anticipated Professor Karl Harries of Germany, by a few months. It is earnestly to be hoped that the discovery will prove to be of practical value. If it does, the

rubber manufacturing industry will assume much larger dimensions, for if rubber were very cheap many rubber goods would be much more largely used.

That the world is soaping itself more vigorously is shown by the ever-growing exports of British soap manufacturers. In the last three years exports have risen from £1,500,000 to nearly £2,000,000 in 1911. The imports are very small, amounting to about £300,000. The soap industry has benefited greatly by the cheapening of alkali; and large as our exports already are, the spread of civilisation will yet make hundreds of millions of new customers for the soapmaker.

The trade in musical instruments has made a considerable advance; it is one in which our imports are greater than our exports, although the latter are growing.

BRITISH COMMERCE IN MUSICAL INSTRUMENTS

Year	1.—Pianofortes		Year	2.—Other Instruments	
	Imports for Home Use	British Exports		Imports for Home Use	British Exports
	£	£		£	£
1904	621,000	137,000	1904	470,000	126,000
1907	650,000	165,000	1907	371,000	128,000
1910	504,000	218,000	1910	327,000	159,000
1911	561,000	345,000	1911	308,000	193,000

The greater part of the trade is, of course, in pianofortes; and it will be seen that while imports have been somewhat falling since 1904, when separate classification was first made, the exports of British pianofortes have considerably increased. It is to be feared that many of these British instruments are fitted up with imported actions, but undoubtedly the status of the British trade as a whole has improved. Here, again, we have an industry which demands high qualities for its competent and successful conduct. The first-class pianoforte manufacturer needs to be both an artist and a scientist, and a high degree of skill is demanded from his workmen. The first-class modern pianoforte is a thing of refined artistry, and the great success of Germany has only been achieved by long-continued and pains taking endeavour.

The following facts speak for themselves: In 1910 Germany exported 63,016 pianofortes, worth 37,970,000 marks, and in 1911 she exported 73,311 pianofortes, worth 44,134,000 marks. Thus, in 1911 German exports of pianos were worth about £2,200,000, against our exportation worth £345,000. It is impossible to doubt that here, as in the case of the chemical industry, Germany has earned her success by the work of her men of science.

A surprising feature of the trade returns is the extent of our commerce in toys and games. The exports of toys and games of British make have risen from £588,000 in 1909 to £721,000 in 1911, while our imports of this kind are now worth about £1,300,000 a year. Allowing for home production, we see how well the children of the present generation are catered for, the commerce in their toys being actually greater than the commerce in many important articles of utility a generation or fifty years ago.

The trade in oilcloth and linoleum begins to bulk for a good deal in the tables of our export returns.

BRITISH COMMERCE IN OILCLOTH AND LINOLEUM

Year	Imports for Home Use	British Exports
	£	£
1900 ..	120,000	1,313,000
1907 ..	98,000	2,381,000
1910 ..	72,000	2,632,000
1911 ..	91,000	2,690,000

In this trade, exports have doubled in the last ten years, and may easily double again within a short period. Germany is a competitor in oversea markets, but there ought to be more than room for a number of competitors in a world in which the standard of comfort is rising so rapidly.

Our review has ranged over a wide miscellany of trades, and, on the whole, we have good reason to be satisfied with the position. We have noted many points of an encouraging character, and we have had evidence where a new direction of energy is called for. We are confirmed in the opinion that modern commerce is as yet only on the threshold of achievement, and that in a world that will soon number some 2000 million people the twentieth century will come to witness trade exchanges of much greater magnitude. Even in the most advanced countries it is as yet only the minority who are really customers for each other's productions. When we have learned how to promote the free consumption of the goods a scientific industry can now so easily produce, trade will be counted in tens or even scores of millions where we now count millions.

PROBLEMS OF DEMOCRACY

How Under the Pressure of Their Social Conscience the British People May Establish Industrial Civilisation

THE NEW IDEA OF THE MINIMUM MAN

SUCCESSFUL as the government of the people by the people and for the people shows alike in actual achievement and magnificent promise, we must not blind ourself to the fact that the system of democratic rule, which seems happily destined to spread over the greater part of the earth within the next generation or two, has its special problems. Every form of government had its problems: those of despotism are the most insoluble. For a despot has to keep the general people oppressed, and yet maintain in his kingdom sufficient strength of mind and character to prevent the utter stagnation that means national decay. In oligarchical government, whether by an aristocracy of birth or a plutocracy continually recruited from the money-makers, there is often more scope for the best minds among the populace to rise by patronage or original power to a position among the governing classes. Hence, one of the most active causes of discontent among the people is partly removed. Their natural leaders are often won away from them; and, moreover, the ambitious men of genius of humble origin are sometimes able to induce the governing classes to undertake certain measures of popular reform that satisfy for a while the chief wishes of the people.

Somewhat of this slow and yet solid kind of progress in government obtained in England when the landed aristocracy took over the rebellion started by the middle classes against the absolute power of the king, and succeeded in making themselves quietly and steadily more powerful than the monarch. More fortunate than the patricians of ancient Rome, the English nobility of the eighteenth century kept the people controlled and yet pacified, and prevented the rise of any Imperial despot. And by absorbing most of the best minds in literature, science, and industry, and by allowing men of new wealth, like the Pitts, to have an active share of power, they preserved the stability of the country and allowed scope for the development of the ambitions of the middle classes. And owing partly to the success of the new American democracy, and partly to the wonderful results of the industrial revolution, the British middle classes were soon enabled to recover the power they had lost in the days of Cromwell, and engage with advantage in a struggle with the aristocracy for political dominion.

The middle classes won by adopting the ancient tactics of the nobility; that is to say, they came forth as champions of the general rights of the populace. Very likely in both cases there was no selfish thought at the back of the champions of the people, either in the fight against the king or in the contest of the burgesses against the nobility. Class interests and feelings of social justice happily coincided, and in combination they were irresistible.

All this is a matter of recent history in many civilised States besides Great Britain. Only in France, towards the end of the revolutionary period, did a powerful middle class use the populace for its own ends in the struggle against the aristocracy, and then resolutely set itself to check and quell the popular aspirations which it had evoked. Much of the troubles and political convulsions that have disturbed the evolution of government in France during the last hundred years can be traced to the defeat of the ideals of the working class by the landed peasantry and bourgeoisie. If the French middle classes do not become fairer-minded, we may yet see another great revolution in their country, of which the Syndicalists are the forerunners.

Yet a similar prophecy might vainly have

been made in regard to Germany, when the middle classes there were frightened by the spread of Social Democracy, and rallied to the military caste. But already a practical majority of the middle order of society in Germany has gone over to the working classes, and begun to co-operate with the Labour leaders in transforming the theoretic Socialism of Karl Marx into a practical weapon of political reform. The consequence is that modern German Socialism is becoming an advanced kind of Radicalism that will surely sweep a large part of the middle classes of the country into the political army organised by the leaders of the labouring orders.

Popular Government in America Only a Stucco Front

In an entirely different way, a similar fusion appears to be taking place in the United States. There, in the birthplace of the modern democratic movement, an intricate web of causes has for years so operated that popular government looked like becoming merely the stucco front of a far-reaching, showy, but unsound system of plutocratic rule. Neither the American Republican Party nor the American Democratic Party was what it pretended to be. For a considerable number of politicians on both sides were puppets moved by strings secretly pulled in Wall Street. Multitudes of low-class emigrants, and a general absorption in large opportunities for money-making offered by a vast, rich, and undeveloped country, kept the reins of power in the hands of a small body of professional politicians, many of whom lived on commissions and bribes. These kept-men managed to preserve the façade of democratic institutions, but in reality the chief political power resided in the hands of railway magnates, bankers, and the great captains of industry.

The Awakening of the Americans to Their Lack of Liberty

But the United States was so rich that for many years the people were somewhat cynically disinclined to trouble about what was going on. Now, however, the Americans are awakening; they have suddenly disbanded both of the political armies that kept them amused by their mock battles, and they have begun to organise themselves for the reconquest of their political rights. Sooner or later, if they do not slacken, they are bound to triumph. For the one thing that their enemies cannot do is to fight them in the open. They can hire armies—they are doing so already—but they cannot lead their host as Theodore Roosevelt and Woodrow Wilson are leading the insurgents of both of the old parties.

An alliance between Roosevelt and Wilson and the honest Labour leaders would completely break the power of the led-captains of the working class and of the professional jugglers who keep the middle classes in subjection to the hidden plutocracy. Only by dividing the new forces of progress can the sons of Mammon continue to rule. But even then their means of dominion could not last very long. For the political conscience of the American people has been aroused and exalted in a way that reminds an English observer of the days when Abraham Lincoln changed the Yankee into a hero. The great democracy of the United States will again save itself, and the influence of its fresh achievement will tell on the whole civilised world.

At present, however, the motherland and some of the youngest plantations of the Anglo-Celtic race seem to be taking a chief part in working on a vast scale some of the ultimate problems of democracy. Speaking in a large way, the forms of government in the British Empire have been kept fairly pure and effectual.

The Extraordinary Rapidity of Complicated Social Reform

Corruptions there still are, but they are, on the whole, without any wide and profound effect on the national efficiency of the main machinery of government. The fair and important social reforms that the greater number of the people want, and know they want, get put in train well within a single generation. This is extraordinarily rapid, when regard is had to the widespread interests often involved, and to the need for exhaustive discussion, and for provoking into action one of the busiest and most cautious of nations.

But we have not yet solved the problem that many ancient democracies attempted to avoid, and were destroyed through their evasion. It is not extravagant to say that the failure to deal with the demands of the working classes has ruined more middle-class Governments than any other cause. Modern democracy, in which the entire people have at least a show of power in the conduct of the State, seems first to have become a force in certain Italian urban communities in the Middle Ages. The burghers in some towns expelled the feudal nobility, or deprived them of power, with the assistance of the populace. But, as a general rule, the merchants and small

manufacturers were not inclined, in the day of their power, to deal fairly with the manual labourers whom they employed. The burghers wished to preserve in matters of politics the same mastership that they exercised in industrial affairs over their assistants and journeymen.

Not infrequently the hired craftsmen, and the lower classes generally, found that in exchanging feudal rule for burgher government they had lost by the exchange. Their new masters came into personal contact with them during the greater part of their waking hours, and were more pettily and continually tyrannical than the old, careless, warlike nobility had been. And there was no fairly disinterested third party to whom they could appeal. In almost every Italian commonwealth this condition of things was perceived by some enterprising nobleman or by some merchant prince, and turned to personal advantage. Sometimes the populace rebelled against the burghers, and gave the captain of an army the opportunity to come forth as a champion of popular rights, and quell the governing middle class, and usurp the seat of power. In other instances, some of the most powerful and wealthy of the burghers, like the Medici of Florence, curried favour with the discontented working class, and won their way to the position of fairly kindly and paternal despots.

Will Socialism Ever be Used as a Stepping Stone to Personal Dominion?

A few years ago some of the American plutocracy professed to be afraid that Roosevelt would veer round to Socialism, and use it as a weapon in an attempt to build a strong-handed, one-man power out of the increasing discontent of the working people and a large part of the middle classes. Of course, there was no truth in the rumour. Yet the fact that it could have been conceived as the merest possibility in one of the most modern of States rather goes to show that we have not yet completely escaped from the chief danger in ancient democracies. There are, indeed, some extreme forms of Socialism which, if made attractive to a well-organised majority of the working classes, could be used by an ambitious man as an instrument of dominion. Lassalle, the great German Socialist, once dreamt of climbing to something like supreme power by this method.

It all comes to this: that if the modern democratic movement is to endure and develop, the just aspirations of the working classes will have to be satisfied. Happily, the time has gone in our country when a man with the fine character and generous ideas of John Bright was convinced that a measure for establishing a ten-hours working day was utterly wrong. Splendid as were many of the political virtues of Bright, he was inclined to take at times the old middle-class view of the position of the working people. Sound as his theories about freedom of contract appeared, they had, when reduced to practice, the look of favouring the interests of the employing class.

The Tory Advance Towards Democracy, and Subsequent Retreat

It was, perhaps, incidents of this sort that enabled Lord Randolph Churchill to obtain for a while an unexpected success with his gospel of Tory Democracy. Had a large body of Liberals continued to be of the way of thinking of John Bright, we might have seen in our country an alliance between the working people and the old landowning aristocracy which would have produced for a generation or so a strangely disturbing effect on the fortunes of the party that has always prided itself and with some good grounds for its pride on representing the forces that make for social reform.

Happily, all this is now becoming a piece of dead history. Absorbed in foreign affairs, the Conservative Party in the days of its power somewhat neglected the domestic problems of our industrial civilisation, and thus gave the other party in the State the opportunity of recovering its position. In the meantime the working people began to organise themselves in a political way for the promotion of their special interests; and though their organisation is still far from being completed, enough has been done to command the attention of both of the old parties in the State. The vast working-class vote cannot be ignored; and we are inclined to think that in the near future the efforts made to obtain it will tend to blur the distinction between the domestic policies of the Liberals and Conservatives.

The Ideal Balance—Agreement as to Ends, Difference as to Means

Looking at the matter from a national point of view, this readjustment of political ideas is a happy event. An agreement in regard to the ends to be achieved, and a difference in regarding the means to those ends, will transform our system of party government into as impartial a machine of democratic rule as is possible in the present state of human nature. The motherland is

in the fortunate position of having still attached to her young communities, mainly of working people, which are leading the way in many respects in political experiments and social achievements. Taking our race at large, it now possesses an extraordinarily varied fund of experience in government. We have in India perhaps the finest system of bureaucracy that has ever been developed, and by applying it to Egypt we have regenerated that country, raising its peasantry to a height of security and prosperity unknown to their ancestors in the golden age of the best of their native despots.

Employers and Employed Antagonising Instead of Aristocracy and Democracy

At the other end of the scale, our race has a Labour Party exercising supreme control over Australia. The British Empire at the present time is, in short, the most marvellous laboratory of forms of government that has ever existed. Indeed, nothing comparable to it, nothing remotely approaching it, can be found in the past history of mankind. Considering all these things, no reason can be found for supposing that the democratic movement will fail among the far-scattered race for want of political instinct and political knowledge.

Not the least remarkable of the social experiments that the mother country is beginning to undertake is the solution of the conflict between capital and labour. The fact that we have become the storm-centre of the industrial unrest that is beginning to trouble the whole civilised world may prove to be a blessing in disguise. For it is forcing us to take the lead in settling one of the main problems of democracy. As we have seen, the conflict between the employing class and the labouring class has usually become acute as soon as an old aristocracy was deprived of the control of affairs. In our country, where matters are more subtly complicated than in ancient societies, it is impossible to draw a clear line between the interests of the old nobility and the interests of the new men of wealth who have arisen in large numbers in the last hundred years.

The Complicating Effect in This Country of the Social Conscience

For, though some of the old nobility dislike the rich manufacturers, and would side with their working people in a conflict, partly perhaps from patriotic tradition, and partly perhaps from something like malice towards the new plutocracy, yet in many cases the new men of wealth themselves have for social reasons gone over to the aristocratic party.

Yet, in spite of all this confusion, the old lines of conflict in a democratic State between a rich and a powerful middle class, and an overworked and suffering working class, still proceed on the larger and rather vaguer distinction between employers and employed. And a democratic State could be as disastrously divided on the new lines as on the old. Happily, however, our people have not only a remarkable political genius, but they possess also, on the whole, a lively and earnest social conscience. Indeed, we sometimes think that it is from the fair-mindedness and social conscientiousness of our race that its admirable political genius is derived. We have produced some great political thinkers, but we stand almost alone in the number and quality of the political seers that have arisen among us. Some of these men, like Carlyle, on the one side, and Ruskin on the other, have touched the conscience and mind of the people in a way comparable to the influence exercised by the prophets of Israel on the religious feelings of their countrymen. The general result is that most of us are now convinced that a nation does not live by its economic forces alone. It is possible so to change the attitudes of will, and the social emotions of the political and industrial masters of a people, as to make them an instrument of general social betterment.

Paths that Converge Towards the Brotherhood of Man

And this is what is now going on. There are four converging paths to the establishment of the brotherhood of man. There is the gospel of Christ, which has been preached in various ways to the nations of Christendom for nineteen hundred years, without apparently becoming a common rule of life. Then there is the recent application of science to industry, which, by giving mankind a marvellous control over the natural resources, will surely end some day in the practical abolition of poverty. Again, there is a direct political action in the general interests of the nation, which can sometimes do a great deal to equalise the fundamental conditions of the various classes. And lastly there is the possibility of the creation of a new system of relations between the working staff of a business and the directing and financing bodies, which, it is thought, may uplift the workers and give them a new and larger interest in the industries they greatly help to carry on. Naturally it is to immediate political action, and to large and perhaps gradual reforms in industrial organisation, that most practical men hope for some satisfactory solution of the urgent and important problems of capital and labour.

In the considered opinion of the present

writer, the children of our nation will feel grateful to us for the leading part that we are being forced to take in solving the main domestic problem of modern democracy. By bearing the heat and the burden of the grand crisis in industrial civilisation, we shall, if we emerge successfully, ensure to succeeding generations a long and peaceful period for the further development of scientific industry, more remarkable in its effects than the period of freedom from foreign aggression which our forefathers a hundred years ago purchased for us at Trafalgar and Waterloo.

The Evolution of Mutual Understanding, Conciliation, Arbitration

If our modern urban civilisation has not made us soft and slack and neurotic, our present social difficulties will prove to be a stimulus to high and enduring efforts in under-pinning the structure of our State, and settling it firmly on a larger and stronger foundation. Already our most practical men are busy creating a basis of mutual understanding, of conciliation, of arbitration, and of constitutional practice in industrial disputes, in which it appears quite probable that we shall one day excel the world.

Alongside of all this new machinery for adjusting the relations of capital and labour, there is the serious question of fluctuations in employment that must be regulated. For a hundred years it has been noticed that our trade oscillates in periodic cycles of good and bad times, which usually occur at intervals of ten or eleven years. The tide of industrial activity pulsates in a general ebb and flow, and influences the entire economic life of the nation. And it has lately been ascertained that similar eras of progress and reaction follow each other with some regularity in France and Germany, and other manufacturing countries.

The Difficulty of Fluctuation in Employment, and Need for Foresight

And though it is true that the times of stagnation are but the shadows cast by the progressive periods, during which the weakest factories and most backward managements go under, so that the next movement of expansion starts from a higher level of efficiency, yet the recurring periods of disaster often involve in unmerited suffering a large body of working people. To the individual artisan, a forward movement of trade over the crest of prosperity and down the trough of depression may mean permanent degradation. He cannot wait, like the capitalist often can, for the returning era of expansive trade. He lives by selling his labour, and he is compelled to sell it at once. So it happens that two hundred thousand skilled men occasionally find themselves, through no fault of their own, without work and wages. And at the same time the cause of unemployment acts in widening circles through the grades of unskilled and general labourers. Insurance against unemployment is very well in its way, but it has to be paid for, and it cannot pretend to avert the fundamental disaster, any more than a life policy can avert death.

Yet even this universal fluctuation in employment might largely be checked by statesmanlike foresight. Our national and local authorities are estimated to spend 150 millions sterling yearly on works and services. It surely is not impossible so to adjust this enormous outlay as to counteract the ebb tides recurring in private industries. Such a change, it is pointed out, would evolve no expenditure except forethought, and would be a preventive instead of a palliative. Distress would not be relieved but obviated, probably to a considerable extent.

The New and Spreading Idea of the Minimum Man

More indirect in appearance, but more fundamental in reality in its bearing on the general problem of our industrial democracy, is a new idea in politics which is being evolved from the clash of individualism and self-help and the theory of Socialism and State aid. Individualism aims at the State doing less than it ought; Socialism aims at it doing more than it can. But between these two extremes there is a middle way, and the people of our nation are taking it. It leads to the idea of the Minimum Man. The State is definitely to see to it that each of its subjects attains to a minimum, whether in wages or in medical care, in housing or insurance, in education or in leisure, in employment, in discipline, or in food. Beyond this minimum there will be freedom for each person to make the best of his life. Such at least is the idea. If it can be reduced effectually to practice, the supreme danger to modern democracy will be overcome. Moreover, the human strength of our race will be increased in an extraordinary way. And if the general spread of some degree of comfort does not bring about in the people at large any weakening of character, any softness of spirit, any slackness in handing on the torch of life, two small islands off the coast of Europe may again astound the world by an eruption of genius.

Father's Mother

1. **Full maiden name** .... 2. **Date of birth** ....

3. **Birthplace : Town** ....County or Country..

4. **Residences, principal** ....

5. **Occupations at successive ages** ....

6. [1] Lesser diseases to which there was any special liability	In youth	....
	In middle age	....
	In advanced age	....
[1] Serious illnesses, accidents and operations	In youth	....
	In middle age	....
	In advanced age	....

7. **If dead, cause of death and age at death** ....

8. **Date of marriage**.............................. No. of [2] sons { born .... reaching maturity ...... No. of [2] daughters { born .... reaching maturity ......

9. **Presence of any special taste, defect, gift or peculiarity of mind or body.**

....

Important

(1) The Presence of Consumption, Rheumatism, Gout, Diabetes, Cancer, Heart or Kidney Disease, Epilepsy, Paralysis, Apoplexy, Insanity, Neurasthenia, Hysteria, Alcoholism, Mental or Nervous breakdown should be particularly noted.
(2) It is very desirable that miscarriages and still-births should be included in the total of children born ; but children resulting from a previous or subsequent marriage should not here be included.
(3) If details are known concerning brothers and sisters of grandparents or parents or half-brothers and sisters of informant, they should be recorded on a blank sheet or a separate form.
(4) In the case of Female children being married, the husband's surname should be added (in brackets).
(5) In giving particulars of children (pages 5 to 9) it is very desirable that *every* pregnancy, whether miscarriage, still-birth or full-time, should be included in its proper order.

	Father's Father	Father's Mother
SEX OF CHILD, F. Female, M. Male		
Age for which description is given		
10 **Adult or present height, inches (no shoes)** or *v s* (very short), *s* (short), *m* (medium) *t* (tall), *v. t.* (very tall)		
11. **Adult or present weight, lbs.** or *s.* (slender), *m.* (medium), *c.* (corpulent)		
12. **Colour of hair (before graying)** *a.* (albino, white), *f.* (flaxen), *y-br.* (yellow-brown), *l-br.* (light brown), *m br.* (medium brown), *d br.* (dark brown), *n.* (black, *nigrum*), *cl r* (clear red), *d r* (dark red), *d b r.* (dark brown red), *s r.* (sandy red)		
13. **Colour of eyes** *p bl.* (pale blue), *d bl.* (dark blue), *bl br* (blue with brown spots), *l br.* (light brown), *d br.* (dark brown), *n.* (black), *y bl* (yellow blue-grey or green), *r br* (reddish brown).		
13a. **Note if colour differs in the two eyes,** *dif.* **or if eyes constantly wander or twitch.** *tw*		
14. **Complexion or skin colour** *bl.* (blond), *i.* (intermediate), *br.* (brunette), *d br.* (dark brown), *n.* (black, *negro*). *y* (yellow), *y br.* (yellow-brown), *r br.* (reddish-brown).		
15. **General Mental ability** *1.* (poor ; failure to advance at school Age and class or standard), *2* (medium to good), *3.* (exceptionally good).		
16. **Special ability in scientific research :** Note—In each ability the grades to be as follows *1.* (poor), *2.* (medium to good), *3* (exceptionally good)		
17. **Ditto in organisation or administration**		
18. **Ditto in music** *m*, **drawing** *d*, **painting** *p*; **sculpture** *s*.		
19. **Ditto in literary composition** *l*, **oratory** *o*.		
20. **Ditto in mechanical skill**		
21. **Ditto in calculating**		
22. **Ditto in remembering**		
23. **General bodily energy** *1* (very inactive), *2* (ordinary), *3.* (exceptionally energetic)		
24. **Condition of sight** *1.* (blind), *2.* (imperfect, wears glasses), *3* (ordinary), *4* (strong)		
25 **Age when sight defect, if any, developed** or, *c.*, (congenital, born defective)		
26. **Colour-blind ?** State variety		
27. **Condition of hearing** *1.* (deaf), *2* (defective), *3* (ordinary), *4.* (strong)		
28 **Age when hearing defect, if any, developed** or *c.* (congenital, born defective)		
29. **Condition of speech** *n.* (normal), *l.* (lisping), *s* (stammering), *d.* (dumb, speech unintelligible)		
30. **Age when speech defect developed** or *c.* (congenital).		
31. **Temperament** *p.* (phlegmatic, slow), *m* (melancholic, pessimistic), *s.* (sanguine, optimistic), *c* (choleric, passionate), *e* (excitable, emotional), *n.* (nervous, quick).		
32. **Use of hands** *a.* (ambidextrous), *l* (left-handed), *r.* (right-handed).		
Defects of bodily form as below Mark (X) any that may be present 33. **Birthmarks**		
34. **Hare lip** *h l.*, **Cleft palate** *c p*		
35. **Abnormal fingers or toes**		
36. **Asymmetry of trunk**		
37. **Other traits not included above.** Their nature should be specified.		

FACSIMILE REPRODUCTIONS FROM THE TWELVE-PAGE PAMPHLET ISSUED BY THE EUGENICS EDUCATION SOCIETY TO GATHER PARTICULARS OF FAMILY RECORDS OF THREE GENERATIONS

MORE KNOWLEDGE WANTED

An Appeal to the Public to Help in a Scientific Study of the Transmission of Desirable Qualities

THE PROBLEM OF STERILISATION

We have seen what the American Eugenists have achieved already, but we observe that their valuable and striking results all deal with the realm of what we have called Negative Eugenics. They tell us about feeble-mindedness and epilepsy, and the neuropathic or insane tendency, and the manner of their hereditary transmission, but the problem immediately before us is that of Positive Eugenics, which must depend upon exact knowledge of characters as worthy as mental defect and epilepsy are unworthy. The bare truth is that knowledge is still lacking. The Americans are the first to investigate human genetics for eugenic purposes, by means of the only method which yields real results. They have naturally begun with the most pressing and most promising problems, which all deal with undesirable qualities: and the similar study of desirable qualities has as yet only reached the stage of issuing schedules regarding musical and mathematical talent, as we have seen.

No doubt the pioneer work of Sir Francis Galton is on record, but we now see that that merely establishes the fact of hereditary transmission in the realm of desirable qualities. No one can read "Hereditary Genius," or the later inquiries into the families of Fellows of the Royal Society, people whose names occur in "Who's Who," and so forth, without seeing that valuable qualities are transmitted. But before this primary piece of knowledge can be applied to practice, even in the smallest degree, it is plain that we require to know how the transmission occurs—in what degrees, with what limitations, and under what conditions. The Mendelian law is not referred to in any of Sir Francis Galton's studies of human heredity, its application to man has been strenuously denied by his official followers in this country, and yet we have seen that until this law is applied to the human case we can have no utilisable knowledge at all in the realm of Positive Eugenics. What, then, is to be done at this juncture?

Undoubtedly the demand for more knowledge, so widely made at the International Eugenics Congress, held in London in July, 1912, must be translated into action. The list of papers at the Congress shows at a glance that the kind of knowledge required for Positive Eugenics does not exist in any appreciable degree. Nothing in the programme was so significant as this glaring but inevitable omission. Such being the case, Eugenists have to ask themselves where and how the necessary knowledge can be obtained; and the clear answer is that it cannot be obtained without the help of the public. The public is the material in which the necessary facts and laws are illustrated and exist. If the botanist wants material for knowledge, he goes to the living world of plants; if the astronomer wants knowledge, he looks to the heavens; and if the student of human heredity wants knowledge, he must go to the living world of men. So far as morbid heredity is concerned, this can be done without much difficulty, for the record of prisons and poorhouses and asylums and colonies for defectives are available, and we have seen how excellently they are now being searched and amplified for eugenic purposes. But the case is very different when we wish to learn about healthy and valuable characters. Now we have not the prison or asylum population to deal with, but the public at large; and difficulties of no ordinary kind face us.

People are by no means so sure that they wish to be catechised about themselves and their relatives. The facts are not at all readily accessible. It is not entirely outside the realm of the possible that people may be

willing enough to tell us about their creditable relatives, but chary of undue discussion of the others. We may hear about all sorts of exploits of the heroic order, and duly note them, only to learn later that these tales are not wholly unvarnished, and that the doctrine about telling nothing but good of the dead has been remembered, to the gain of charity, but at the expense of truth.

When the German "Society of Race-Hygiene," which is still only a young body, makes further progress, and when the official resources of the German Empire are made available for the study of the people of the Fatherland, no doubt the case will be different. But in the United Kingdom and the United States people are by no means accustomed to much questioning, and are very far from certain that the answers may not be used to their detriment. Yet without the hearty, responsible, patient, and widespread co-operation of the public, the necessary knowledge of human genetics cannot possibly be obtained.

Sir Francis Galton's argument that it could only be disastrous to go to the public with pretended knowledge may appear sound, but the case of eugenics is unique, unlike that of any other science, in that the material for knowledge must first be educated, and its sympathies enlisted, before the knowledge can be obtained.

The Mistake of Supposing that the Social Stratification of the Nation is Biological

Unfortunately, in this country, certain forces have been at work which are anything but calculated to serve eugenics in this respect. Those who are "what eugenists are not," as was maintained in the second chapter of this section, have tended to alienate public opinion by their very common assumption that the social stratification of our nation is also biological; and thus no serious attempt has been made to learn from any but a few exceptional and favoured quarters, where definite genetic results were quite unobtainable, so powerful was the overlying influence of education, favouritism, and opportunity. But in the United States, fortunately, the case is different. There the social stratification is much less definite and rigid; and the American school of eugenics has not yet published a word to assert or suggest that it holds the ludicrous belief in the biological superiority of the wealthy and the "well connected," which often means the "undetected," as the Gilbertian Duke of Plaza-Toro reminds us.

On the contrary, the American Eugenists are now setting to work, on a large scale, to do what is required for the purposes of Positive Eugenics; and particular attention is here directed to their methods, which urgently require imitation, especially since the population of the United States shows such extraordinary and unexampled racial admixture that it is by no means the best on which to begin such inquiries, and the results obtained therein can by no means be made available as if they necessarily applied everywhere else. But as to the soundness of the American methods there can be no question; and even if the problem be made additionally difficult for these investigators on account of racial admixture, no doubt in time they will be able to ascertain proportionately more extensive laws of human inheritance.

Free Inquiry Must Look for Facts Irrespective of Social Status

In the first place, it is made clear by the American inquirers, and must always be asserted by those who follow them, that they receive facts in absolute confidence, that the names of those who supply the facts will never be published, and that even addresses are only asked for in order that, if there is no objection, further inquiries may be made, if necessary. The student of human heredity is no "respecter of persons." A properly filled in record of a pedigree, showing some trait and its distribution from generation to generation, is of infinitely more value to him, though it comes from the humblest quarters, than the most pretentious but inexact record of "blue blood." Exact facts are alone material, and all exact facts are equally material.

On the day on which eugenics begins to think in terms of unit-characters, instead of such things as "success in examinations"—in terms of elementary genetic units of the composition of man—all questions of caste and class cease to have any meaning.

All Members of the Human Species Suitable Material for Eugenic Study

A definite trait, unquestionably valuable, like the ability to be unruffled where many other people would lose their temper, may be displayed, of course, in the courts of kings or the courts of slums, and no sane person doubts for a moment that the laws of its transmission, if it be transmitted, will be the same in either case. Those laws are now unknown, and we need to know them. It is not even known at all whether this trait is a unit, or a complex of two or more units, nor has anyone yet determined the influence of nurture, in the widest sense, upon its development or non-development; and

what is true of this trait, the first that happened to occur as an example, is equally true of hundreds of other traits, or complexes of traits, upon which, as soon as possible, it is the ambition of Positive Eugenics to pronounce and to act. And of not one of these is there any reason to suppose that the necessary knowledge may not be obtainable at any social level the members of which will be good enough to help us.

That, then, is the first point; these inquiries must be neither democratic nor anti-democratic, but simply human. They are about mankind in general, a definite biological species, and all members of that species are suitable material for eugenic, or rather genetic, inquiry in a countless number of directions as to which our present ignorance is all but absolute. Many of these characteristics or traits are doubtless of no significance to eugenics, which is perfectly indifferent as to their multiplication or disappearance. But we have long ago learnt from Darwin how certain characters of living things are "correlated," as he said, with others, in a fashion which he could not explain, but which he did great service in noting.

An American List of Traits about which Data are Desired

Modern Mendelism has given us a host of examples which show that, though the particular amount of hair on the face, or the liking for society as against the liking for seclusion, to choose examples at random, are of no eugenic importance in themselves, yet the study of the transmission and the associations of such traits may lead us to the understanding of others which concern us vitally, for their eugenic worth or unworth.

From a lengthy list of "examples of traits about which data are desired," issued a few months ago by the American eugenists, the following may be quoted as illustrations: tall stature (over 6ft. 2in. for males, or 5ft. 10in. for females), short stature (under 5ft. 3in. for males, or 4ft. 5in. for females), corpulence or slenderness, red hair, face dimples, aquiline nose, pug nose, any striking family "cast of mood," usual enthusiasm or indifference, perseverance or capriciousness, tendency to economy or extravagance, short-sight and long-sight, special ability in athletics, drawing, painting, modelling, instrumental music, singing, mechanical work, inventiveness, mathematics, language, literary work, business; and family achievements in a multitude of professions and traits. There has been prepared an admirable and simple form, which anyone can fill in with a little trouble and intelligence, and which is quite different from anything of the kind that has been used for such purposes hitherto, though at first one might suppose that this form is only a repetition of many which have been used in this country. These forms are arranged for separate families, with as numerous individuals as possible, and each is meant for the record of a single trait (for instance, dimples or capriciousness), giving the number of relationships of the members of a family that display it.

The Generations through which it is Helpful to Trace Family Traits

There is also room for the drawing of a genealogical table of the family in question, on a simple plan, with squares for the males and circles for the females, so that the distribution of the definite trait in question can be seen at a glance, and readily studied from the Mendelian standpoint.

The form asks that information may be given as to whether a particular trait is present or absent in the following relatives, embracing, it will be seen, four generations.

1 Father	11 Mother's brothers
2 Mother	12 Mother's sisters
3 Brothers	13 Own cousins, father's side
4 Sisters	14 Own cousins, mother's side
5 Father's father	15 Brothers' children
6 Father's mother	16 Sisters' children
7 Father's brothers	17 Wife (or husband), if any
8 Father's sisters	18 Consorts' ancestors
9 Mother's father	19 Consorts' collaterals
10 Mother's mother	20 Own children (if any)

Of course, there is room for error here, and for the "personal equation," but those factors enter more or less into all scientific work, and they can largely be guarded against and allowed for even here. These blank forms are only being sent to people who may reasonably be expected to use them with intelligence and honesty; they involve some little trouble in filling, though really there are many duller games, and there can be no advantage to anyone in filling them up badly.

How Universities, Schools, and all Intelligent People Can Help

All the data will be held as strictly confidential, and no names will be published. In universities and colleges, notably including those which are devoted to special subjects, such as colleges of music, there exist large numbers of intelligent young people who will be pleased and interested to fill up such forms to the

best of their ability; and there can be no doubt at all that, within a very few years, we shall be able to state the laws of transmission of many familiar and desirable traits at least as accurately as we can already define the genetics of certain defects and abnormalities. The urgent *desideratum* of the present time will then be met to some extent, and we shall know not merely that desirable human traits are transmitted, in the mental and moral realms as well as in the physical, as Galton asserted long ago, but *how* that transmission occurs, even to the extent of being able to predict the chances of its occurrence in given instances.

Eugenics the Most Complicated of the Sciences, and the Most Dependent on Others

It has long ago been evident that eugenics has a bewildering variety of aspects and relations, each of which requires special, expert study. The reader has only to note at random a few of the subjects already discussed in this section in order to see that this is really the most complicated of all the sciences, and the most dependent upon all the others. The idea that any one man can possibly be a first-hand expert or authority on the whole of eugenics must be abandoned. All sorts of special knowledge are required: and the time has come when we must organise our forces in order to obtain it, just exactly as we require to organise and divide and specially train our forces in such matters as medical and surgical research. Here, again, our American friends are in the van, and we must learn from them.

Within the present year the announcement has been made of a well-thought-out organisation of the Eugenics Section of the American Breeders' Association, already referred to; and since much depends upon the way in which we set to work, the reader, especially in Great Britain, where we lag far behind, will do well to note carefully the following description, recently issued by authority.

An Outline of the American System of Inquiry into Eugenics

"The work of the section is twofold—that of the Eugenics Record Office and that of the committees. . . . The Record Office seeks to accumulate and study the records of physical and mental characteristics of human families, and to educate the public as to classes of fit and of unfit marriages. Its work is done by means of (*a*) correspondence, (*b*) the acquisition of family records on special blanks, and (*c*) the inquiries of field-workers investigating either in conjunction with institutions or independently. Its records are kept in a fireproof vault and thoroughly indexed.

"The committees serve as centres for special inquiries or for education. They are of two sorts: (*a*) technical committees and (*b*) local committees. Technical committees are composed of professional men trained for special inquiries. They further investigations in their subjects and advise the Record Office. The local committees are to serve as local centres for collection and study of data and for education. It is contemplated that such committees will be formed in connection with various universities and at other intellectual centres."

Ten technical committees have now been formed, each composed of specially qualified persons, and their respective subjects are well worth enumerating, especially as in due course we shall expect to receive valuable new knowledge from their labours. They deal respectively with heredity of the feeble-minded, heredity of insanity, heredity of epilepsy, heredity of criminality, heredity of deaf-mutism, hereditary eye defects, immigration, sterilisation, genealogy, and the inheritance of mental traits.

The American Committee on Sterilisation, and Its Delayed Report

To one alone of these committees, which have been in being only during the present year, need we refer here—namely, the committee on what is called sterilisation, and our reasons for doing so will doubtless commend themselves to the reader.

In the first place, a preliminary "report of recent investigations as to the results and practicability of sterilisation" was communicated to the International Eugenics Congress in London in July, by the chairman of the committee; but far more important is the second reason for reference to this matter—namely, that it has unfortunately been discussed and been the subject of extremely definite assertions of all kinds without anything like adequate knowledge. In this country distinguished writers are to be found who are heartily in its favour, and many more who are as heartily against it. Further, it has lately been the subject of a long and bitter controversy in one of the leading medical papers, where the controversialists mostly directed themselves to something entirely different from what is meant by sterilisation.

The assertion which we desire to make here is a very simple and quite invulnerable

one—that in the absence of any real knowledge of the subject the duty of responsible people is to suspend judgment at least until the American committee issues its final report. The present writer is privately but officially informed that the report in question cannot be expected until two or three years have elapsed. During that period all real knowledge and experience of the subject will be sent to the committee from all parts of the world where such knowledge and experience exist; and the study of this large mass of data, which will certainly provide much conflict of evidence, may be hoped to yield us really trustworthy conclusions at the end of that time.

The Need for Withholding Judgment Until More is Known

Till then anyone who is heard confidently asserting that sterilisation is always or never right or wrong, safe or dangerous, effective or ineffective, must be dismissed as the more ignorant the more he asserts. No one yet knows what needs to be known of this subject.

Its importance is extreme, and has long demanded the kind of study which it is now at last to receive. Proposals for simple sterilisation, without mutilation of any kind, were first made on the Continent many years ago, and were notably advocated in this country by Dr. R. R. Rentoul, of Liverpool, to whom much honour is due for his courage. Their object was, and is, to protect the future without the necessity of segregating or limiting the freedom of those who are unworthy from the point of view of parenthood. This is definitely a humane object, notwithstanding its frequent misrepresentation, and it is so regarded by many individuals who have, of their own free will, already subjected themselves to the simple procedure required. About that there is no question, but about the ultimate consequences of this procedure there is every question, simply because there is not enough experience behind us.

The Constitution and Methods of the American Committee of Inquiry

The American Committee which has faced the complicated problems involved has been formed none too soon, since various States in America have already adopted laws which enforce or permit sterilisation; and without in any way attempting to prejudge the question at issue, or to forecast the verdict of a few years' hence—which may very likely be favourable—we can at least be certain that in this case law has run in front of knowledge, though not in front of public opinion in the States in question. Nothing is more liable to bring eugenics into disrepute than action in front of knowledge, which its illustrious founder so consistently and rightly deprecated. Let the reader who is already familiar with the style of this controversy, and the contributions to it hitherto, compare his recollections with the following description of the methods now in employment.

The "Committee of Study and to report on the best practical means of cutting off the defective germ-plasm in the human population" has begun by calling in the help of seventeen advisers, each to deal with special aspects of this vastly difficult question. Such branches of thought and knowledge are each represented as not merely surgery, physiology, and so forth, but also ethics, economics, statistics, law, history, and "woman's view-point." It is further announced, under the heading "International Associates," that "the committee will seek to obtain through eminent specialists in each of the several modern nations data and opinions on the problems of this investigation for their respective countries. It is hoped to have the following countries represented—England, Germany, France, Italy, Austria, Russia, Japan, Holland, Belgium, Norway, Sweden, Denmark, and Spain."

The Official Statement of the Problem as Viewed in the States

The following paragraphs reproduce, for the reader in Great Britain and elsewhere, the well-considered and valuable "General Statement of the Nature of the Problem, and the Reasons for this Investigation":

Eugenics is the science of race improvement through the application of the laws of heredity. Among other things, it seeks to cut off the inheritance lines and thus the supply of the socially unadapted. Obviously this remedy must apply only to those thus unadapted *through an imperfect inheritance*, and this investigation is, therefore, thus limited.

In recent years society has been aroused to the fact that the number of individuals within its defective classes has rapidly increased, both absolutely and in proportion to the entire population; that eleemosynary expenditure is rapidly increasing; that some normal strains are becoming contaminated with anti-social and defective traits; and that the shame, the normal retardation, and the economic handicap of the presence of such individuals are more keenly felt than ever.

Along with penal, hospital, and eleemosynary care a remedy looking toward the cutting off of the supply of defectives is being sought

on every hand. Among other remedies the sterilisation of degenerates is proposed and has become a law in eight States. This proposed scheme for race improvement thus comes within the range of practical legislation, and the need of a thorough and judicial investigation becomes exigent.

With a view to determining the eugenic possibilities and limitations of sterilisation, the Eugenics Section of the American Breeders' Association has appointed a committee commissioned to investigate the problems connected with the proposed sterilisation of certain defectives and degenerates. It is the purpose of this committee to provide for a thorough, first-hand, and expert investigation into the medical, surgical, biological, social, legal, eugenic, and ethical aspects of the problem.

The Spirit in which the Investigation is Being Pursued

It is the further purpose of the committee to make its work a scientific investigation and not a propaganda. It will, therefore, strive to maintain a non-partisan attitude, to collect as much pertinent, authentic data as possible, to record first-hand observations, to hear expert testimony from men of science, and leaders of thought and public opinion, to weigh the arguments of advocates and opponents, and to present to the public an accurate and unbiased report.

Whether wholly of defective inheritance, or mostly of good inheritance, but suffering from an insurmountable hereditary handicap, members of the following classes are socially unfit, and their supply should, if possible, be eliminated from the human stock: (1) the feeble-minded class, (2) the pauper class, (3) the inebriate class, (4) the criminal class, (5) the epileptic class, (6) the insane class, (7) the constitutionally weak, or the asthenic class, (8) those predisposed to specific diseases, or the diathetic class, (9) the deformed class, (10) those with defective sense organs, as the blind and the deaf, or the kakaisthetic class.

This is the classification of defectives from the social point of view; obviously it is also partly medical, partly legal, and is in some part biological, although a purely biological classification would be very complex, since it must be based upon unfit traits of defective inheritance and their combination into the various legal, medical, and social types. In the above classification many of the classes overlap. Thus, for instance, factors of feeble-mindedness doubtless run through all of the other classes. Of the other types, insanity and criminality often overlap, and so on.

The Various Proposals Made to Prevent the Deterioration of the Race

No two individuals belonging to the same general group will have exactly the same combination of traits, and one individual may belong to one only, or to several types of the socially unadapted; albeit because members of each of the above enumerated classes possess in common a number of traits incompatible with the best social adjustment this classification is the one that fits best into the social scheme and is the basis upon which society, with the aid of the several social and biological sciences, can well proceed to investigation of the possible measures of eliminating its defectives.

Several means have been suggested as the proper agents for effecting this scheme of race betterment. Among these are: (1) sterilisation, (2) life segregation, or segregation during the reproductive period, (3) restrictive marriage laws and customs, (4) systems of mating purporting to remove the defective traits, (5) general environmental amelioration, (6) eugenic education of the public and of prospective marriage mates, and (7) laissez-faire. Which of these remedies shall be applied? Shall one, two, several, or all be made to operate? What are the limitations and possibilities of each remedy? Shall one class of the socially unfit be treated with one remedy and another with a different one? Shall the specifically selected remedy be applied to the class or to the individual? What are the principles and limits of compromise between conservation and elimination in cases of individuals bearing a germ-plasm with a mixture of the determiners for both defective and sterling traits? What are the criteria for the identification of individuals bearing defective germ-plasm? What can be hoped from the application of some definite elimination program? What practical difficulties stand in the way? How can they be overcome? Those and other questions arise, hence this investigation.

The Duty of Caring Alike for the Individual and the Community

Until the committee reports, it will behove us to be careful as to what we assert or do in the name of eugenics. But when we come, in the course of this section, to the problems of our defective population, we shall see that, in the great majority of cases, our duty to the individual as such is clearly to take care of him or her, in the interests of the individual, who is only a child in ability for self-protection, and in the interests of the general community. In all such cases we need not wait for the report of the committee, which is so indispensable in other respects.

Here, for the present, we must leave the American school of eugenics, having already learnt much from them, and hoping in due course to learn much more. Meanwhile there comes up for consideration a large and varied assortment of new matter necessary for eugenics, which came to light at the First International Eugenics Congress. But before we can apply such knowledge, what about human individuality and liberty?

MARS AND MINOR PLANETS

Has a Planet Been Destroyed by Explosion in the Space Between Mars and Jupiter? Or has a World Failed to Form?

THEORY AND KNOWLEDGE ABOUT MARS

THE planet next outside the orbit of the earth is Mars. Because of its ruddy, fiery colour it has received the name of the ancient god of war. In the earliest pages of this work we made some acquaintance with Mars, and with the strange markings on its surface, believed by many to show the work of intelligent and highly civilised beings, who have attempted, by a vast system of irrigation, to make the greatest possible use of the planet's diminishing supply of water. That interpretation of the appearances on the surface of Mars is in several ways a very doubtful one; and it is hardly likely that the question will be cleared up in our day, unless astronomy receives the aid of much more powerful telescopes than have yet been constructed. Mars is more than a hundred times as far away as our moon; and perhaps the best telescopic vision which we get of Mars is not very much better than that which we get of the moon with unaided vision. It is well to realise, at least, that those very interesting and surprising suggestions with regard to a Martian population and their mighty engineering works are still very far from certainty. We shall see what has been said on one side and on the other, but let us first review the facts certainly known with regard to Mars.

It is a little planet, very much smaller than our own. Its diameter is only 4800 miles; its surface area a little more than a quarter of the earth; its volume is only about one-seventh, and its mass is less than one-ninth, of the volume and mass of our planet. The density of its materials is considerably less than the average density of terrestrial materials, and gravity on the surface of Mars is only 38 per cent. of what it is with us, so that a mass weighing a hundred pounds on earth would weigh only thirty-eight pounds on Mars.

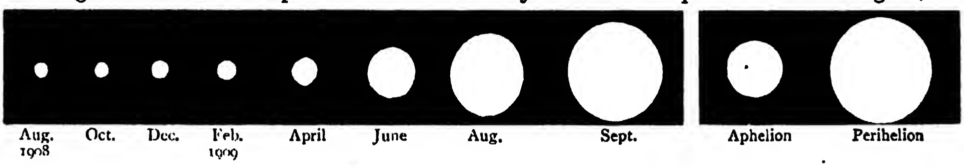
The amount of light and heat received from the sun is, surface for surface, less than one-half of that received by the earth; and this obviously implies a very cold climate on Mars, unless, as some suggest, the thinness of the Martian atmosphere, allowing the sun's rays to pass through very freely, permits a warmer temperature than we should expect from the planet's distance from the sun. The mean distance of Mars from the sun is 141,390,000 miles, as compared with earth's distance from the sun of 93,000,000; and the distance from the sun of Mars at perihelion, or its nearest point, is 128,200,000 miles: and at aphelion, or its furthest point, is 154,580,000 miles. At its nearest point Mars is therefore twenty-six million miles nearer to the sun than at its furthest point, so that its orbit is notably eccentric, and is indeed more eccentric than the orbit of any other of the larger planets, with the exception of Mercury.

The distance between Mars and the earth varies within very wide limits. When Mars is on the other side of the sun from the earth—that is to say, when it is in superior conjunction—its distance from us averages 234,400,000 miles; but when it is on the other side of the earth from the sun—that is to say, is in opposition—its distance from the earth is anything from 35,500,000 miles to 61,000,000 miles, according to the point in the eccentric Martian orbit in which the opposition occurs. Mars is in opposition at intervals of twenty-six months, and at these times is to the south and high in the heavens at midnight. Its disc is at the same time far larger than at any other point in its orbit, so that the times of opposition give peculiarly favourable opportunities for examining its surface. Indeed, the apparent diameter of Mars varies from three and a half seconds at conjunction to twenty-four and a half seconds at opposition. When

nearest to the earth, Mars is a brilliant star of the first magnitude.

Mars completes its orbit round the sun in 687 days, or one year and ten and a half months, and travels along it at the rate of fifteen miles a second. The orbit is slightly inclined to the ecliptic, by rather less than two degrees. The planet rotates on its own axis. The clear markings on its surface have made it possible to determine the speed of that rotation with great accuracy, so that it is known that the Martian day is slightly over thirty-seven minutes longer than ours.

Like the earth, Mars is somewhat compressed at the Poles, which are clearly visible under favourable circumstances by their white ice-caps. Mars further resembles the earth in respect that it does not spin vertically to the plane of its orbit, but its equator is inclined by 24 deg. 50 sec. to that plane, being much the same degree of inclination as that of the earth. Mars, therefore, has seasons very similar to ours, in the course of which the Polar ice-caps form and melt away, and other changes of markings and colour take place.



THE CHANGES IN THE SIZE OF MARS AS VIEWED FROM THE EARTH AT DIFFERENT DATES

In August, 1908, Mars was at the opposite side of its orbit to the earth—some 200 million miles away. The discs show the increasing size of Mars as the earth catches it up, until it passes it, in September, at a distance of 36½ million miles. The gibbous shape is due to part of the dark side of Mars being presented to the earth. The two discs on the right show the relative apparent proportions of Mars when the earth passes it in opposition, first when furthest from the sun (aphelion), and second at its greatest possible diameter, when at its nearest to the sun (perihelion), but 35 million miles away.

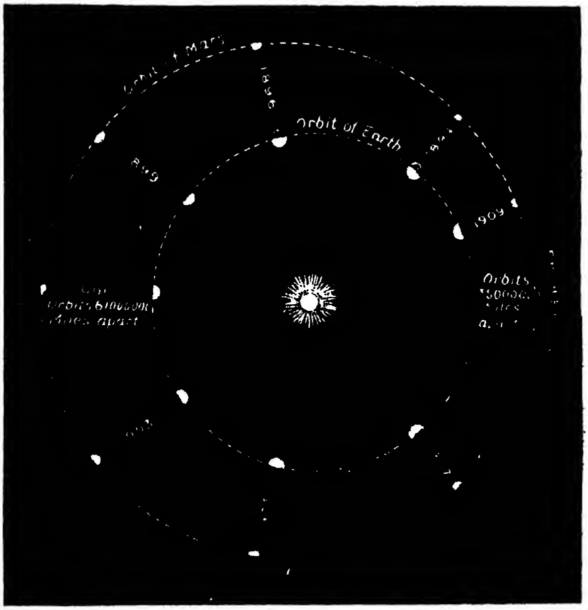
Area for area, the disc of Mars is a better reflector than that of the moon, twice as good as that of Mercury, but far inferior to Venus. Being outside the orbit of the earth, this planet never assumes the crescent phase, but the full circle of the disc is at times slightly impaired, giving Mars the gibbous shape of our moon when about three days from full moon. This occurs when the planet is in quadrature—that is to say, when the lines from earth to sun and sun to Mars are at right angles. To the unaided eye, Mars, like every other planet, appears as a mere point of light and not as a disc at all. If its approximate place be known, it may be distinguished by its red colour, but it must be remembered that several fixed stars are also very ruddy.

Owing to the earth's revolution in its orbit round the sun, the apparent path which Mars traces in the heavens is complicated, when that planet is in opposition, by a remarkable loop which it appears to describe within its normal orbit and in the contrary direction. That is to say, although Mars for the most part moves daily eastward among the stars, it appears when on the opposite side of the earth from the sun, to turn and move westward for a time, and then to resume its eastward journey. This loop in the planet's apparent orbit presented prodigious difficulties to the astronomers of the old days, who regarded the earth as stationary and all other celestial bodies as wheeling about our globe, and they were forced to devise exceedingly complicated movements to account for the apparent retrogression of the planets.

Mars possesses an atmosphere which, though much less dense than ours, resembles it in other respects. Its presence is seen in the fact that the planet's disc is brighter towards the edge than in the centre; for, as the brilliancy of Venus shows, atmosphere is the most effective of reflectors; and the rays of sunlight entering the edge of the disc of Mars encounter a deeper reflecting layer of atmosphere than those rays which fall upon its centre. Again, the markings on the planet's surface are sharply defined only towards the centre of the disc, but lose their clearness, and finally disappear altogether, as they are brought by the diurnal rotation towards the edge. The Polar ice-caps, which increase in size through every Martian winter, and diminish through the summer, are further evidence of an atmosphere in which moisture is carried, and from which it is precipitated in the form of snow; and certain white spots and other markings which appear occasionally, and are inconstant in form and position, are believed to be clouds floating in the atmosphere of Mars.

The spectroscope has shown that this atmosphere is closely similar to our own, and also that it contains aqueous vapour. The light from Mars gives the spectrum of sunlight, crossed by the dark lines which it would exhibit if it had passed through the terrestrial atmosphere. Of course, the light from Mars, before it reaches the spectroscope,

has actually traversed the atmosphere of the earth; and this fact, if it were not provided against, would vitiate the conclusion that these dark absorption lines are due to a Martian atmosphere resembling our own. In order to avoid any such fallacy, astronomers have made simultaneous spectroscopic observations of the light from Mars and of that from our moon, which is practically denuded of atmosphere. Both of these lights have passed equally through the terrestrial air; and the conclusions with regard to the Martian atmosphere are based on the difference between the two spectra. The light from Mars shows absorption lines which are absent from the light of the moon.



ORBITS OF MARS AND THE EARTH, SHOWING THEIR POSITIONS RELATIVE TO ONE ANOTHER AND TO THE SUN

Since the earth goes round the sun in 365 days, and Mars in 687 days, and the earth travels the faster, it happens that when the earth passed Mars on any of the dates shown above, a little over two years elapses before the earth catches Mars up again. This sometimes occurs when the orbits are close together, as in the opposition of 1909, when Mars was observed under favourable conditions.

Mars has two very small moons, which revolve very close to the planet itself. They are so minute that, though often sought for, they escaped observation until 1877, when Professor Hall, of Washington, made them out after long and sedulous watching with the best telescope which existed at that time. He had even given up the search as hopeless, when his wife implored him to make another attempt; and the discovery of the first moon was followed after a few nights by the discovery of the second. Though not observed until so recently, these two moons had long been expected, on quite insufficient grounds. It was then thought, incorrectly, that whereas earth had one moon, Jupiter had four moons, and Saturn had eight; and it was felt to be suitable that Mars should have two satellites, in which case each of these three planets outside our own would have double the number possessed by the planet within its orbit.

Perhaps this mistaken theory had something to do with the extraordinary literary accident by which Dean Swift, writing early in the eighteenth century, not only represented Mars as having two moons, but made a very near guess at their distances from the planet, and at the speed of their revolutions round it. Describing in "Gulliver's Travels" the work of the astronomers of the imaginary Laputa, and remarking that they have "glasses far excelling ours in goodness," the chronicler proceeds as follows: "This advantage hath enabled them to extend their discoveries much farther than our astronomers in Europe; for they have made a catalogue of ten thousand fixed stars, whereas the largest of ours do not contain above one-third part of that number. They have likewise discovered two lesser stars, or satellites, which revolve about Mars, whereof the innermost is distant from the centre of the primary planet exactly three of his diameters, and the outermost five; the former revolves in the space of ten hours, and the latter in twenty-one and a half." Actually, the innermost revolves in the space of seven hours and thirty-nine minutes, and the outermost in thirty hours and eighteen minutes. It was an astonishingly near guess.

The two satellites were named by Professor Hall, after two characters in Greek mythology, Deimos and Phobos, who were attendants on the god of war. Deimos, the outer satellite, is distant about 14,600 miles from the centre of Mars; it revolves, as was mentioned above, in somewhat over thirty hours; and, the period of its revolution differing so slightly from that of the planet's rotation, it must pass very slowly across the Martian sky. Indeed, about

five and a half days must elapse from the time when it rises to the next time it rises. The orbits of both of the satellites are circular; and lie in the plane of the planet's equator. Deimos is estimated to be about five or six miles in diameter, and to throw on Mars a light equal to about one twelve-hundredth part of the light which our moon throws on the earth.

A Little Moon that Rushes Round Mars Three Times a Day

Phobos, the inner satellite, is at a distance of only 5800 miles from the centre of Mars—that is to say, a distance not greatly exceeding the diameter of the planet itself. It is a little larger than its companion moon, having a diameter of about seven miles; and because of its nearness to the planet it is a much better luminary than the other, throwing a light equal to about one-sixtieth of the light of our moon. Its period of revolution—seven hours and thirty-nine minutes—is the shortest known period in the whole solar system. It makes over three circuits of Mars in the Martian day, and consequently rises in the west, and sets in the east. These two moons—one crossing the sky from east to west so slowly as to take over two and a half days from its rising to its setting, the other crossing the sky rapidly and frequently in the contrary direction, and both going through all their phases of new moon, crescent, and full moon in these brief periods of thirty hours and seven and a half hours respectively—would seem strange if we could only see them.

Professor Lowell's observations of Mars, to which we alluded in our first chapter, have shown that the darker areas on the surface of the planet are not seas, as they were formerly supposed to be. They are crossed by many of the so-called canals; and whatever may be the nature of these canals, no permanent linear markings of that kind could exist on the surface of the sea. Moreover, these dark areas undergo a seasonal change in colour, being greenish-blue for part of the year, and a ruddy yellow for the rest of the year.

Theories Accounting for the Changes of Colour in Parts of Mars

There is much to be said for his conclusion that these so-called seas are areas of vegetation. A similar view is held by Professor Pickering, who does not, however, at all believe that the canals are artificial works. He interprets them as belts of some low kind of vegetation arising in the neighbourhood of linear cracks in the surface of the planet, and fostered by gases or moisture escaping through these cracks from the interior. The dark spots at which the canals join, commonly called oases, are in his view craters, from which the cracks radiate in some such way as they do on the surface of the moon.

Dr. Alfred Russel Wallace, who formulated simultaneously with Darwin the theory of natural selection, has brought forward another and very different hypothesis. In an essay entitled "Is Mars Habitable?" he answers that question very decidedly in the negative, on the ground that the temperature of the planet's surface must be very low, not only because of its distance from the sun, but also because of the thinness of its atmosphere. He regards the canals as cracks arising from the contraction of a superficial layer, formed, after the planet had solidified, by the falling in and melting of a swarm of asteroids and meteorites, and considers that Deimos and Phobos are the only remaining representatives of this invading multitude.

A Summary of What is Known of the So-called Martian "Canals"

There are other theories which might be mentioned, but perhaps there is rather too much theorising, in astronomy, upon insufficient data. In view of the fact that clearly defined linear markings, though of different appearances, are characteristic of Mercury, and again of Venus, and again of our moon, it is not surprising that linear markings should characterise Mars also. It seems hardly necessary to go out of our way to explain them as the result of prodigious engineering works.

Among many writers on this subject, Dr. Dolmage seems to sum up most judicially the present position of the question, as follows: "It does not seem too much to say that a further improvement in optical power might entirely subvert the present notions with regard to the Martian canals. Therefore, until we get a still nearer view of these strange markings, it seems somewhat futile to theorise. The lines which we see are perhaps, indeed, a foreshortened and all too dim view of some type of formation entirely novel to us, and possibly peculiar to Mars. Differences of gravity and other conditions, such as obtain upon different planets, may perhaps produce very diverse results. The earth, the moon and Mars differ greatly from one another in size, gravitation, and other such characteristics. Mountain ranges so far appear typical of our globe, and ring-mountains typical of the moon. May not the so-called

'canals' be merely some special formation peculiar to Mars, though quite a natural result of its particular conditions and of its past history?" In other words, the secret of the Martian canals is still unsolved.

In our review of the solar system from the sun outward we have come to one large planet after another—Mercury, Venus, Earth, Mars; and presently, after crossing a vast space, we shall come to other much greater planets—Jupiter, Saturn, Uranus, Neptune. But in the region at which we have arrived, between Mars and Jupiter, there is no large world, although the presence of some such planet might have been expected. There is here an apparent interruption of the uniformity of the system. Instead of the orbit of a single large planet, we find in this region a belt which is traversed by the orbits of a vast number of small planetary bodies, which are commonly known as the minor planets, asteroids, or planetoids. In the region within this belt, and again in the region outside of it, the formation of planets by the falling together of meteorites has proceeded to its normal conclusion, so that definite large worlds, with or without satellites, have come into being; but over the area of this belt, which lies between Mars and Jupiter, the normal formation of a planet has been prevented, possibly by the disturbing influence of the vast mass of Jupiter.

That curiously regular increase in the distances of the planets from the sun, which was first noticed by Titius about the middle of the eighteenth century, and, after its publication by Bode, became known as Bode's Law, required the existence of a planet in this belt, which instead is scattered over with asteroids. It is now fairly certain that there is nothing at all in Bode's Law, except a coincidence. The law needs a good deal of straining to suit the distances of some of the planets, and Neptune disregards it altogether. Bode's formula is as follows: Set down the numeral 4 repeatedly. Leaving the first 4 as it stands, add 3 to the second, add 3×2 to the third, 3×4 to the fourth, 3×8 to the fifth, and so on, doubling the multiplier every time. Divide the resulting numbers by 10, and we are supposed then to have the mean distances of the series of planets from the sun, if the mean distance of the earth from the sun be taken as unity. The fifth term in this series requires a planet at a distance from the sun of the earth's distance multiplied by 2·8, and for this missing planet astronomers sought eagerly. For Bode's Law had not yet been discredited, and, quite apart from that theory, it was obvious that there was a large gap between Mars and Jupiter.

MARS IN THE OPPOSITION OF SEPTEMBER, 1909

This drawing, executed by M. Antoniadi at the Meudon Observatory, France, shows the appearance of the planet at 11.40 on the night of September 20, 1909, two days after it was nearest to the earth. The Antarctic snow-cap is to be seen at the top, and canals are visible in the lower half.

Towards the close of the eighteenth century an association of astronomers was formed for the purpose of hunting for the planet which was believed to be there. It was known that the object of their quest must be very small in size, or it would not so long have eluded observation. The first capture of an asteroid fell to Piazzi, a Sicilian astronomer, on the first day of the nineteenth century. He had long been engaged in a very exact method of mapping the sky, by which he determined the relative positions of all the stars within any particular area on several successive occasions. By this means he was able to detect if any star should move relatively to its neighbours and thus declare itself to be a planet. More than a hundred and fifty areas of the sky had thus been examined without success, when a comparison of four successive observations of the constellation Taurus showed Piazzi that a certain small star within it had moved from one observation to another. This

stranger was at first supposed to be a comet; but Bode, on hearing of its movements, claimed it for the planet which was required by his law of planetary distances from the sun. It was found to pursue an orbit in the vacant space between Mars and Jupiter, and was admitted, under the name of Ceres, as a member of our system. Its course through the heavens was calculated by the mathematician Gauss, so that it could be found and identified on any future occasion. In the following year a second asteroid was discovered, and named Pallas; this was followed by the discovery of Juno and Vesta; and the four most conspicuous minor planets having thus been identified, the search was discontinued for many years.

How the Smaller Asteroids have been Discovered by Photography

It was taken up again about the middle of the century with unexpectedly rich results, and now about seven hundred asteroids are known to astronomy.

Ceres, the largest of the minor planets, has a diameter of about five hundred miles. Of all their number, Vesta, which is the brightest, is the only one visible to even the keenest unaided vision. Many of them are very small indeed, and can only be seen through the most powerful telescopes; and in all probability there are many hundreds, or perhaps thousands, more which are too small to be seen at all. The search for asteroids, which was long dependent upon direct telescopic observation, is now, like so many other scientific undertakings, a matter of photography. A camera is attached to a telescope moving by clockwork in such a way as to continue pointing to the same fixed stars. These stars therefore come out in the photograph as white points. But a planetary body, if there be any such within the field of the telescope, shows itself otherwise. It comes out, not as a point, but as a short white line, because of the movement it has made in its orbit during the exposure of the plate. This method, devised in 1891 by the German astronomer Wolff, has resulted in the discovery of many of the smaller asteroids.

The Romantic Finding of the Lonely Little Planet Eros

It was by this method of photographic observation that the minute planetary body known as Eros was discovered in 1898. It is doubtful whether Eros can be regarded as belonging to the swarm of asteroids which circulate between Mars and Jupiter, because, though part of its orbit lies outside that of Mars, it is for the most part between the orbit of Mars and that of the earth. Eros has an exceedingly eccentric orbit, and approaches to within fourteen million miles of the earth's path, so that with the exception of the moon it is by far the nearest body to the earth. But its very small diameter, which is less than twenty-five miles, kept it secret until sensitive plates were exposed night after night to the sky. Eros is so very far separated from the other minor planets that its origin is probably quite independent of theirs. It is to be regarded rather as a tiny planet, whose orbit lies between the earth and Mars.

The asteroids cover a very wide belt. Medusa, the nearest to the sun, is little more than twice the distance of our earth from the sun, while Thule, the outermost of all is more than four times as far from the sun as we are. The belt containing the orbits of these planets has therefore a width of over one hundred and ninety million miles, though the greater number circulate within a belt less than forty million miles in width. The orbits of the asteroids are very various, often extremely eccentric, and are in many cases very steeply inclined to the ecliptic or to the plane in which the sun rotates and the various members of his planetary system on the whole revolve around him.

Have the Asteroids been Formed by the Explosion of a Planet?

The mass of these tiny planets is very small. It is estimated that together they do not exceed a quarter of the mass of our earth. It is not yet clearly known why this space in the solar system, which should normally be occupied by a single planet with its satellites, is tenanted instead by an incoherent crowd of asteroids. It was at first believed that the minor planets were the scattered fragments of a planet which had in some way exploded and its pieces scattered. That view, however, has been given up, because it is known that the orbits of all these fragments, however greatly they might otherwise diverge, would have to pass through one point common to all of them—namely, the point at which the supposed explosion took place—but the widely various orbits of the asteroids do not, in fact, pass through or even near any common point, but form an inextricable tangle. This theory that the asteroids originated by explosion may, however, be amended so as to avoid the objection we have just mentioned. Some believe that the fragments formed by the first explosion subsequently exploded again, and yet again; and in that case a numerous swarm

of asteroids, such as we see, might very well arise, having no common point in their orbits. But the theory, even in this improved form, is met by the further objection, which is practically insuperable—why should a planet explode? and why should its fragments explode again?

Have the Asteroids been Drawn into Their Positions by the Influence of Jupiter?

The other and more probable theory is that the matter destined to form each planet of our system was originally distributed in rings of meteorites round the sun, just as rings of meteorites circulate round Saturn; and that, although in the case of other planets the meteorites fell together into one body, those which circulated in the region between Mars and Jupiter were prevented from doing so by the enormous disturbances caused by the gravitation of Jupiter as he revolved in his orbit. The mass of Jupiter exceeds that of all the other planets put together, and may have had the effect of preventing the coalescence of the asteroids.

Indeed, there are certain facts which show in a very interesting way the power which Jupiter has exercised over the asteroids. If the distances of their various orbits be set down graphically on a chart, it is immediately apparent that at certain distances from the sun there are many of these orbits crowded closely together, but that at other distances there are blank spaces which contain no asteroids. It has been ascertained that these blank spaces are at exactly such distances from the sun that any asteroids having orbits in them would travel round the sun in such periods as to come frequently into the same relations with Jupiter at the same points in their orbits. That is to say, no asteroid could retain an orbit in any one of these spaces, because Jupiter would so regularly and so often pull on it in the same way as to force it into an orbit at some other distance from the sun. Jupiter has swept these spaces clear of asteroids.

The Counter-influences of the Mighty Jupiter and the Sun

For example, at that distance from the sun at which an asteroid would revolve exactly twice round the sun for one revolution of Jupiter, any such asteroid would be pulled out of its orbit by the constantly recurring effect, in exactly the same place, of Jupiter's gravitation. This effect would return at every revolution, until the asteroid had been forced to travel round the sun in a period which would not synchronise with Jupiter's period. The same process would affect any asteroid travelling, for example, five times round the sun for every two revolutions of Jupiter, so that a chart of the orbits of the minor planets contains blank spaces corresponding to a considerable variety of these numerical combinations. And although Jupiter's attraction has thus acted in a prohibitive way upon minor planets which might otherwise have occupied orbits where there now are blanks, it must be remembered that the same attraction is always affecting the orbits of the asteroids, which are consequently always changing their paths to some extent, under the influence of this mighty planet.

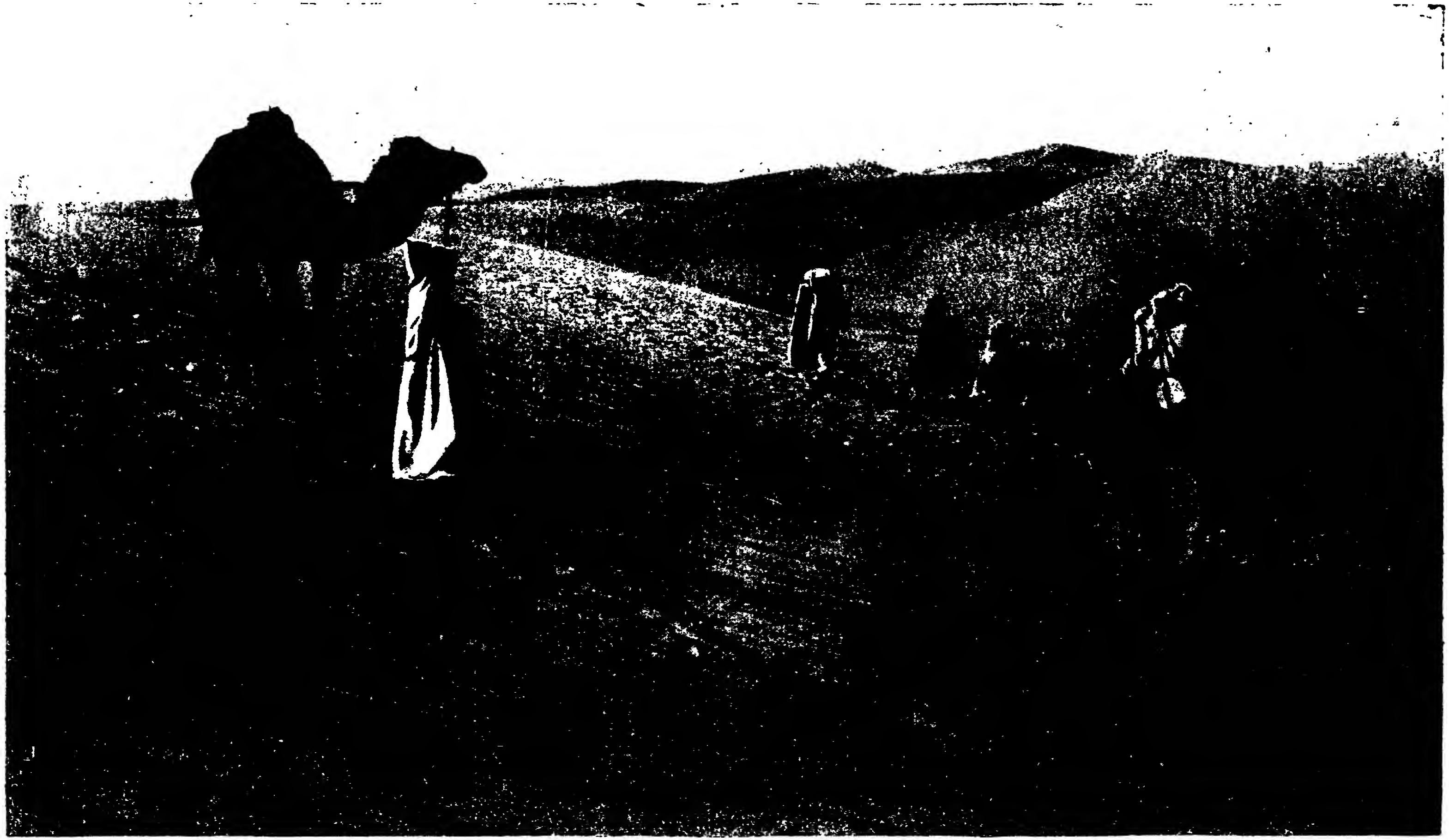
The task of computing the orbits of the various asteroids, and of keeping track of them in the sky, has involved enormous labour, not only because they are so numerous, but even more because of the complexity which is introduced into their movements by the powerful neighbourhood of Jupiter. These calculations were until recently carried out by the collaboration of many astronomers, especially in Germany, but it is now realised that it is possible to be too laborious, and that the ends of science will be sufficiently served if the chief asteroids are watched and the rest are abandoned.

The Possibility that the Asteroids are Jagged and Shapeless Masses

Little is known of the asteroids themselves. Certain observers have reported an atmosphere about some of the largest of them; but the presence of any such mantle of air is extremely improbable, if not impossible, owing to the weakness of gravitative force in such minute bodies, and there appears to be no confirmation of its existence. The most significant fact yet ascertained is that several of them vary greatly in brightness from time to time, and that these variations in reflective power are very swift and erratic. This irregular fluctuation in brightness seems to show that the asteroids are not spherical but are shapeless lumps, detached mountains hurtling along through space, and presenting now a side, again an edge, and again a corner to the earth.

This variation has been remarked particularly in Eros, the nearest to us, but also in several others. Obviously this jagged and shapeless state of the asteroids would very well suit the theory which regards them as fragments of an ancient planet torn asunder by explosion. But it is not unsuitable to the other theory, which regards them as huge meteorites that have failed to coalesce into a planet.

MOUNTAINS WHERE THERE IS "NO RAIN, NOR ANY DEW. NEITHER FIELDS OF OFFERING



A RAINLESS REGION OF AFRICA, WHERE THE SANDS OF THE DESERT HAVE OBLITERATED THE WORKS OF MAN EXECUTED UNDER A KINDLIER CLIMATE

RAIN AS FRIEND AND FOE

Why It Rains—How Much It Rains—and the Things that Rain Can Do

THE RED RAIN OF SUPERSTITION

RAIN consists of drops of condensed water of considerable size which fall from a height through the air at a comparatively rapid rate. The fall is usually due to the running together of the fine drops in a raincloud. The combined drops have a smaller surface in proportion to their weight than the individual drops possessed before their combination; the air accordingly offers them less resistance, and they fall, therefore, more readily and rapidly. Though as a rule rain falls from a cloud, it occasionally, as is well known, happens that rain falls from a cloudless sky. This happens when the air contains too few dust-particles to provide for the condensation of the numerous little droplets that go to the making of a cloud. The moisture, therefore, instead of beginning in little droplets as a cloud, condenses at once as big drops on the scanty dust-particles, and falls at once as rain.

Rain does not necessarily reach the earth. A cloud may rain, and yet the drops of rain may evaporate before they reach the earth, and no doubt this happens more often than is commonly supposed. The condensation that results in rain is quite simple in its general principles. The warmer the air, the more water-vapour can it hold as vapour. When, accordingly, warm air containing a certain quantity of water-vapour is cooled, it becomes, at a certain point—the so-called dew-point—incapable of holding all the water-vapour it could hold when warmer, and the vapour accordingly condenses on any solid, cool particles it can find. A cooling by any means of warm, vapour-laden air is the ordinary origin of rain. This cooling may be effected in various ways. It may be effected by a cool breeze, or by a cold hill, or by expansion—as when a breeze blows uphill. In mountainous districts both the last two conditions of cooling are found, and hence in mountainous districts there is usually a large rainfall.

The cloud that so often attaches itself to the summit of a high peak is not a cloud that has caught there, but a cloud that has been formed there; and often, as the wind blows over a snowy Alpine peak, a cloud streaming from the peak like a pennon demonstrates the condensation of the water-vapour it contains. A very picturesque cloud of condensation is the so-called "tablecloth" of Table Mountain, at Cape Town. The condensation of the steam of a locomotive, and of the breath on a cold day, are illustrations of the same process on a small scale. All that is required is water-vapour to condense, sufficient cold to condense it, and nuclei, such as dust-particles, to serve as centres of condensation.

From what we have already said, it is evident that the distribution of rain must depend largely on the physical features of the land. In a general way, the following rules may be laid down.

Towards the equator the rainfall increases, and towards the Poles it diminishes. The reason of this is that the heat of the tropical zones evaporates the greatest quantity of vapour, and this vapour is readily precipitated. As Bonney puts it: "Most water is spilt near the pump."

Other things being equal, there is more rain near the sea than inland. The reason for this is twofold. In the first place, wind from the sea is likely to contain a quantity of water-vapour; in the second place, the land and the sea are often of different temperatures, and thus a warm, moist wind off one may be condensed by the other. We all know how the warm, moist south-west wind blowing off the Atlantic brings rain to the western and south-western shores.

Other things being equal, the rainfall increases with the height above sea-level,

provided always a height above ordinary cloud-level is not attained. This is due to the action of mountains in condensing water-vapour, as we have already explained.

The average rainfall on the plains of Europe is 22·6 inches per year, whereas in mountainous districts it is over 50 inches. In the valley of the Rhine, the average rainfall is 22 or 23 inches; in the Vosges mountains it reaches 47 inches in certain districts. At Arles, the rainfall is 17·7 inches, while at Joyeouse, in the mountains sixty miles away, it averages 51 inches. At Geneva the rainfall is 32 inches; at the St. Bernard Hospice, 79 inches. The same law is exemplified in England. On the Cumberland coast the rainfall is 35 inches, while in Borrowdale it averages 150 inches, and on the Sty Head Pass has been known to reach 243·9 inches. At Fort William the rainfall is 77·33 inches; on the summit of Ben Nevis, a few miles away, it reaches 129·47 inches.

The rainiest district in the world is probably the lower slopes of the Himalayas. Here all the physical conditions conduce to a heavy rainfall. We have the steaming water in the great Indian Ocean, and the barrier of the Himalayas, which intercepts and condenses the moist monsoons. Even on the delta of the Indus the rainfall is considerable, but it is when the moist currents reach the hills that the really heavy rains begin. At Ulu Selangor, in the Malay Peninsula, there is an average annual rainfall of 323 inches. At Mahabuleshvar, on the western slope of the Ghauts, there is an annual average rainfall of 275 inches; while at Cherrapunji, on the Khasi Hills, 200 miles north of the Bay of Bengal, the average rainfall is almost 500 inches. For the first ten months of last year, indeed, no less than 560 inches fell at Cherrapunji, nor is this a record, for, in 1861, 905 inches were registered, and of that total 366 inches fell in the month of July.

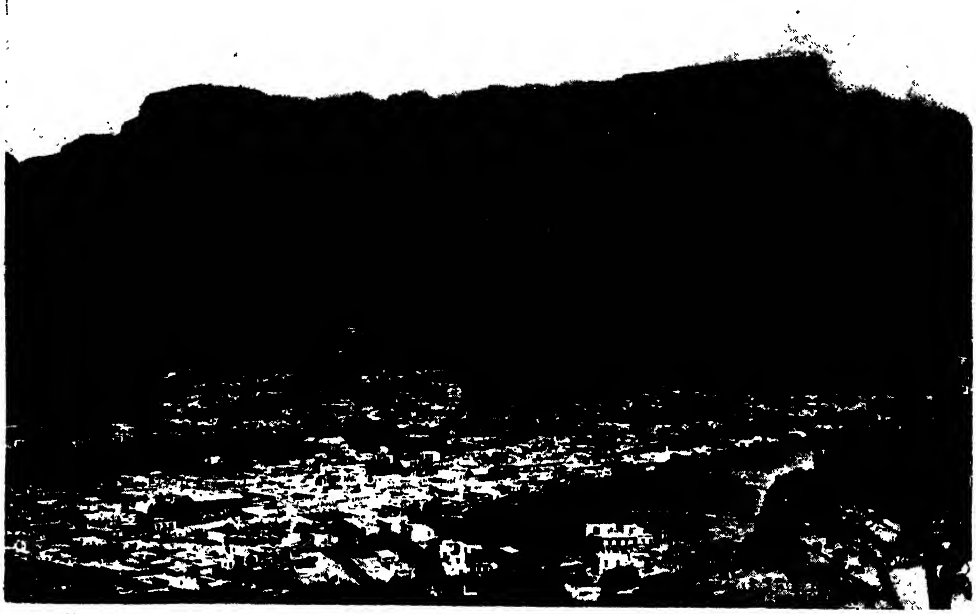


TABLE MOUNTAIN, NEAR CAPE TOWN, COVERED BY ITS TABLECLOTH OF CLOUD

These last figures are startling! Seventy-five feet deep of rain a year! As much rain in a single month as falls on the average area of England in ten years, and as much as falls at Leh, on the other side of the Himalaya mountains, in 100 years! In a single day in this amazing place as much as 40 inches has fallen in twenty-four hours. But this was beaten on one occasion by Sydney, where, in 1860, 82·81 inches fell in the twelve months. Even in Europe there are occasionally terrific rains. At Joyeouse, in France, 31·173 inches fell in twenty-two hours; at Geneva, 30 inches

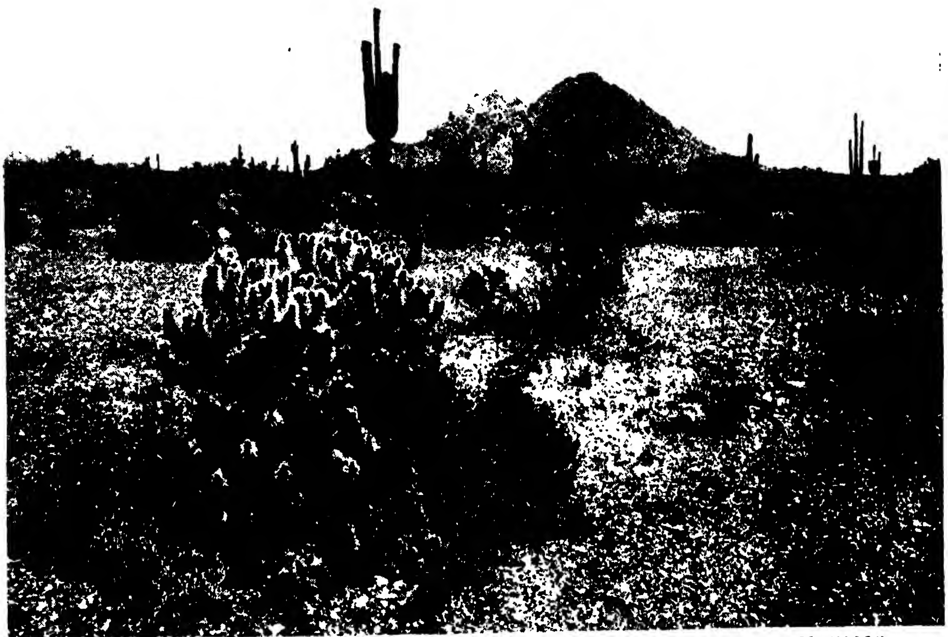
in twenty-four hours; and at Gibraltar, 33 inches in twenty-four hours.

Though we complain of the rain in England we have no rainfalls like this. The average yearly rainfall in England is 34·3 inches, and the heaviest yearly rainfall recorded is 49 inches in 1872. A fall of one inch in twenty-four hours is thought a very heavy rain, and more than four inches in twenty-four hours are rarely registered. Still, it does do better than that sometimes. In 1863 12½ inches fell in thirteen hours at Portree, in Skye. At Seathwaite, in Borrowdale, nearly 6¾ inches have been recorded; and at Ash Hall, in 1880, 2·9 inches fell in thirty minutes, which is the most rapid rainfall officially recorded in England. In the eight rainy weeks which began last December the aggregate rainfall at Oxford was only 9·37 inches. In respect of number of rainy days, Londonderry takes the lead with an average of 243 rainy days in the year; and Weymouth comes last, with only 153 days.

It must be noted that the heavy rainfalls in the tropics are not due to condensation of moisture by mountain-ranges so much as to the condensing effect of cold winds pouring into the tropics from cooler regions. The line of meeting moves north and south with the northward and southward movement of the sun. When the sun is north of the ecliptic they form a zone of clouds north of the equator, and when the sun is south of the equator they form a zone south of the equator. This zone of clouds, says Reclus, "is undoubtedly visible from the nearest heavenly bodies, and must resemble these whitish bands which our telescopes discover on the planet Jupiter."

The movement backwards and forwards of this great girdle of clouds makes a regular alternation of wet and dry seasons in the tropics; and the rainy season is in summer, so that there are clouds and rain just when they are most wanted. In the immediate neighbourhood of the equator there are two dry and two wet seasons. How much rain falls on the tropical seas cannot be calculated, but the amount must be very large. Occasionally the rainfall is so heavy that sailors are able to collect fresh water from the surface of the ocean.

In the temperate zones there are no clearly defined dry and wet seasons, and the rainfall is much more irregular, depending on numerous variable factors. On the South Russian steppes and in the Hungarian highlands the heaviest rainfall is in summer, while in England the heaviest rainfall is in autumn and winter.



TYPICAL VEGETATION IN THE ARIZONA DESERT, WHERE RAIN SELDOM FALLS

In certain regions of the globe there is almost no rain. Very rarely does it rain in the districts south and east of the Caspian Sea, on the South African Karoo, in Southern Australia, in the Arctic regions, in the regions south of latitude 60°, and in the cañon country of Colorado. And a strip of the western slopes of the Andes, extending southwards through Peru and part of Chile from latitude 5° S. to about latitude 35° S., is altogether rainless, all the rain being retained by the mountains that rise to the east. In Peru "the appearance of a cloud is a real event, and the whole population assembles to contemplate this unaccustomed spectacle." Rainless, too, is a belt of land, about 10° in breadth, which, extending across Africa, including the Sahara and Libyan deserts, crosses the north of Arabia into Persia to terminate near the western border of Afghanistan. And still a third rainless region includes Eastern Turkestan, with the Desert of Gobi.


HONEYCOMB WEATHERING AT PORTSCATHO, CORNWALL

Where there is no rain, the contours of mountain and plain have a characteristic monotonous appearance. There are no glens, valleys, and streams—only flat plains and level plateaus. Where there is no rain there is also no vegetation except lichen. Dry, dusty, desolate, is the rainless land.

Where the rainfall is small it is of the utmost importance. On the African Karoo when the rains fail all the vegetation of the Karoo perishes, and sheep and other animals die of lack of food. And when the rains do come the sudden response of vegetation to the moisture is like a miracle. When there is a dry season and a wet season, the wet season is like a resurrection. Reclus describes how in the dry season the soil of the llanos of Colombia dries up: "The watercourses become exhausted; the lakes change into pools and then into sloughs, in the mud of which crocodiles and serpents delight to wallow; the clayey ground shrinks and cracks, the plants wither and are torn to shreds by the wind, the cattle, driven by hunger and thirst, take refuge in the neighbourhood of the great river, and multitudes of their skeletons lie bleaching on the plains. . . . All at once the storms of the rainy season inundate the soil, multitudes of plants shoot out from the dust, and the yellow expanse is transformed into a flowery meadow." It is little wonder that in some savage tribes the rain-doctor is a personage of some importance.

It has often been maintained that trees bring rain and that the felling of forests decreases the rainfall. There is no doubt at all that deforestation diminishes the permeability of soil, and diminishes, too, its capacity for catching and holding water. Trees both collect water round their roots and hinder its evaporation by means of their foliage. Where trees overshadow a road is usually the part of the road that takes longest to dry. Where trees overshadow a spring they conserve its water for the dry seasons. There is no doubt that in these ways trees collect and conserve rain, but whether they actually attract rain is rather a moot question. On the whole, it seems probable that trees do in some way attract the rain. "It must not be forgotten," writes Dr. Robert Brown, "that the slightest difference in the temperature of the soil, especially of the hills, over which a vapour-laden cloud is sailing, may determine whether its moisture will be condensed and precipitated, or whether the misty vapour will float away without the thirsty earth obtaining the benefit of its contents, here more grudgingly bestowed than in the cooler regions near the Poles." Certainly trees do not retain

heat, and they are usually cooler than the soil. Who has not seen how

The swimming vapour slopes athwart the glen,
Puts forth an arm, and creeps from pine to pine
And loiters, slowly drawn.,

Whether by favouring condensation, whether through the high electrical tension of the tops and tips, there seems a fair amount of evidence that forests directly attract rain, and that deforestation leads to drought. The cutting down of trees in St. Helena was followed by a decrease in the rainfall; while a replanting of trees was followed, in turn, by an increased rainfall. In Upper Egypt, destruction of trees along the banks of the Nile was followed by drought, while in Lower Egypt the planting of trees has been followed by an increased rainfall. At the time of the Roman occupation, Tunisia was a fertile land, with about twenty million inhabitants. After deforestation it became a barren plain incapable of supporting vegetable life.

One of the great dangers of drought is liability to conflagrations. After weeks of dry weather, grass and shrub and tree are like tinder, ready to catch fire, and a very small spark may kindle a destructive fire.

Sometimes even the friction of two branches against each other may suffice to kindle a flame. Bush fires and prairie fires sometimes spread for many miles. In 1873 the town of Bona, in Algeria, was encircled by a belt of flame thirty miles deep.

In various districts there are occasional showers of red rain—blood-showers—much disturbing the hearts of the superstitious. Such red rain is most common over the Cape Verde Islands and the countries bordering the Mediterranean, but sometimes it has been seen as far north as England, Germany, and Sweden. It consists of rain mixed with a quantity of red dust, in most cases torn by the wind from the deserts of the north of Africa. When such rain evaporates a residue of fine red dust is left behind.

A RAIN-WROUGHT LANDSLIDE OF BLUE CLAY ON THE HAMPSHIRE COAST

Rain does not work only by the intermediation of a stream or river; as *rain* it plays a direct and important part in moulding the face of the earth. Its action is partly chemical and partly mechanical.

First, we notice its chemical action. Rain is never quite pure water. In the atmosphere it absorbs the atmospheric gases—oxygen, nitrogen, and carbon dioxide. The gases are found to be absorbed in the following average proportions: nitrogen, 64·47; oxygen, 33·76; carbon dioxide, 1·77. It will be noticed that the absorbed gases are not found in the same proportion in which they are found in the atmosphere, and that the carbon dioxide occurs in proportions

thirty to forty times greater than the proportions in which it occurs in the atmosphere. Besides these natural atmospheric gases, rain also absorbs in its passage through the atmosphere a certain amount of nitric acid, sulphuric acid, and salts. Further, it carries down with it germs and dust. As soon as it touches the earth it adds to its chemical contents.

Rain, accordingly, contains various more or less active chemical substances, and has a varied chemical action on the rocks and soil on which it falls. Owing to its oxygen it has oxidative properties, and oxidises or rusts various minerals, such as iron, which it passes over. Owing to the organic matter it contains it has deoxidative properties, and deoxidises other minerals such as gypsum. And, owing to the carbonic acid it contains, it dissolves limestone and marble, carbonate of magnesia, and other minerals. The so-called "pipes" and "swallow holes" found in limestone rock are funnel-shaped cavities corroded in the limestone by rain. If there be no soil on the surface to fill up these holes, they deepen, and may eventually become caverns.

The Karst district of Dalmatia is honeycombed with these holes, which are locally known as "doliniens" or "dolinas." Some of these are deep, some shallow. The deepest is 525 feet deep. At the bottom of these doliniens is found a red earth, which is the insoluble iron residue of the limestone. In northern Bohemia and Saxony hollows three to thirty feet deep, known as Karren or Schratten, are found, and these doubtless are also formed by rain eroding the limestone rock.

Even granite is rotted by water, so that it becomes loose and can be dug into with a spade, and is broken up with clay and sand. In Cornwall and Devon granite is found sometimes rotted 600 feet deep. At Carclaze, near St. Austell, in Cornwall, huge pits, in which a village, church, tower and all, might be entombed, have been dug into granite in search of tin and china clay.

In some cases when rain is absorbed by rock, the rock forms a chemical compound with the water, and undergoes the change known as hydration. Anhydrite, for instance, is converted into gypsum, and increases at the same time about 33 per cent. in bulk.

The mechanical action of rain is quite obvious. Every heavy shower of rain scours and scars the roads and paths with its runnels; and when the rain comes down "in sheets" it carries away the soil as effectively as a river. Where there are trees and vegetation to shield the soil and to hold it together, the rain may fail to remove much of it, but where the soil is unprotected by trees and vegetation it may be borne away very quickly. The destruction of forests, accordingly, though it diminishes rainfall, increases the destructive effect of rain, and many parts of Syria, Greece, Asia Minor, Africa, and Spain have first been denuded of trees by men, and then of soil by the rain. "If," wrote Reclus, "some modern Attila, traversing the Alps, made it his business to desolate these valleys for ever, the first thing he should do would be to encourage the inhabitants in their senseless work of destruction."

AN EARTH-PILLAR IN THE RHÔNE VALLEY

In some cases torrential rain produces floods of mud; and a terrible flood of this kind occurred near Vesuvius in September, 1911. The catastrophe is thus described in a daily paper:

"The torrential rains which fell caused a huge volume of mud and lava to flow down the sides of the mountain, and this, dividing into several branches, swept over the entire country-side, destroying everything in its path. The town of Resina was completely engulfed in it, and the mud

THE CLOUD-BANNER OF THE MATTERHORN

A CLOUD CONDENSING ON THE COLD SIDE OF THE MATTERHORN

A CLOSE VIEW OF THE MIST-LIKE CLOUD ON THE SLOPES OF THE MATTERHORN

The photographs on these pages are by Mrs. Aubrey le Blond, Mr. G. P. Abraham, Messrs. Hawkins & Son, and others.

gradually reached the height of the first-floor windows of the houses. To describe the horror of the scenes that ensued one would be obliged to have recourse to the most awesome incidents in Dante's 'Inferno.' The floating corpses of people who had been overtaken by the terrible flood presented a dreadful spectacle on the surface of the lava. Farming utensils and furniture, together with cows, horses, and various other domestic animals, were also caught up and borne along by the stream. A district known as Miglio di Oro, one of the most enchanting parts of the commune of Resina, has been flooded with mud and totally ruined. The onrush of the lava was such that many houses were swept away bodily. . .

"The scene at Resina is described as dreadful. The impetuous torrent rushed down the mountain-side, and burst with great force against the walls of the houses. The doors crashed in, and the thick stream of lava flooded the lower floors, ruining the interiors of the dwellings. In many cases the mud inside the houses flooded the stairs and the upper floors, breaking practically all the windows in the town. Many persons, particularly women and children, were so terrified by the unusual sight that they had not even sufficient energy left to save themselves, and they were consequently drowned by the awful torrent that still came pouring down the mountain-side. Some time afterwards many bodies were recovered, the faces in every case bearing an expression of the utmost horror. Vivid flashes of lightning and peals of thunder added to the terror of the inhabitants."

A similar mud-stream occurred in the Philippine Islands in 1876. Torrents of rain descended on the volcano Mayon, and a deluge of mud, cinders, and ashes broke down bridges, blocked roads, destroyed villages, and wrecked over six thousand houses.

THE RAIN'S ACTION ON ROCKS—THE GENDARME NEAR THE ORTLER, TYROL.

In other cases rain destroys, not by causing deluges of mud such as we have described, but by producing landslips. In the production of landslips, rain plays a triple part—it disintegrates the soil, it loosens its attachment to underlying rock, and it adds immensely to its weight. Frost, too, takes part in the process, by causing a general expansion of the water in the crevices and pores of rocks and soil, and many severe landslips take place during or after frosty weather. The numerous landslips on the coast attributed to the sea are often mainly due to the rain—the sea merely gives the finishing touch to the loosened mass. Much, too, that is attributed to rivers is really due to rain. We are accustomed to think of rivers carving out the broad valleys, but probably half the work is done by rain, tumbling the banks into the river. All that rivers can do without rain is seen in the rainless cañon country of Colorado, where the rivers make not valleys and glens, but cut steep gorges with perpendicular banks. If the cañon country should come to have a rainfall like Cherrapunji its contours would quickly be completely altered.

The biggest record landslip in England occurred in 1839, between Lyme Regis and Axmouth, and followed heavy rains. On this occasion a deep chasm three-quarters of a mile in length was formed. Most of the great landslips occur not on the coast but among the mountains. In 1806, after heavy rains, a huge mass of pudding-stone broke loose from the Rossberg (a mountain in Switzerland, near the Rigi), and in a few minutes the village of Goldau and three

adjacent hamlets, together with 433 natives and twenty-four visitors, were buried 100 to 200 feet deep. So violent and rapid was the landslip that the friction of the rocks striking and rubbing against each other gave rise to flames which "broke in fiery jets from the half-opened mountain." The lake of Lowerz was partly filled up, and the precipitation into it of such a mass of débris gave rise to waves that swept away all the houses on its banks. Even birds flying in the air were killed. It is estimated that the falling mass contained more than fifty-four million cubic yards, and measured two and a half miles long by 350 yards wide and 35 yards thick.

A landslip in 1881 at the Tschingel Alp had almost as disastrous consequences, destroying the village of Elm and most of its inhabitants. This landslip contained enough stone to build a city the size of Aberdeen. In 1618 a landslip occurred at Monte Conto which buried the town of Plurs, with 2430 inhabitants; and though attempts were made to dig it out no trace of it could be seen. In some cases landslips rush down with the speed of an avalanche, and propel compressed air before them with such force that villages are blown away.

But rain does not always act in such a dramatic and tragic fashion; sometimes its work is merely fantastic. Among its more fantastic efforts are the tall pinnacles of stony clay known as earth-pillars. They occur in the Tyrol, in the Himalayas, in the Sierra Nevada, at Fochabers, in Scotland, and in other parts of the world. Very characteristic and remarkable are the earth-pillars which occur in a glen on the Rittnerhorn, in the Italian Tyrol. The glen has been cut out of clay by a mountain stream, and on either side it is fringed with these earth-pillars, from eight to thirty feet high, and "crowded like tombs in an overfull churchyard." Almost every pillar is capped with a stone or boulder. In the Sierra Nevada range some pillars reach a height of 700 feet. These pillars are simply hardened columns of clay, which, protected by their capping of stone, have resisted the eroding power of the rain, while all the clay round about has been washed away. If the capping stone fall off a pillar, the rain soon melts it away, or melts it down until another stone protects it again from further erosion.

Mount Roraima, in South America, a mountain rising 5000 feet from the plain, and consisting of soft sandstone capped with conglomerate, is thought by some to be really a gigantic earth-pillar, its soft sandstone having been protected from the rain by its hard conglomerate capping. Other curious achievements of the rain are seen in the so-called "Stone Rivers" of the Falkland Islands. Most of the valleys in the East Island are filled with large, angular blocks of quartzite covered with a thin, extremely hard white lichen, which looks like a coating of ice. "Far down below, under the stones, one can hear the stream of water gurgling." Exactly how these Stone Rivers are made is not known, but they are certainly the product of the disintegrative and denudative action of rain.


RESIDUAL BLOCKS OF WEATHERED GABBRO ON THE CROUSA DOWNS, ST. KEVERN, CORNWALL

Other bizarre and rococo results of rain are seen in the remarkable piles of stones found here and there all over the world, and usually known locally by such names as "Devils' Castles," "Lovers' Seats," "Grandfathers' Chairs," and so forth.

A LABORATORY BENEATH THE GROUND

In this photograph of the roots of the laburnum-tree are seen the attached nodules formed by the nitrefying bacteria which appropriate and fix the nitrogen of the air in the soil and use it to build up the nitrates which are absorbed by the roots for the nourishment of the tree

From a photograph by Mr. J. J. Ward

THE GREAT CYCLE OF LIFE

How Energy from the Sun Serves Plants and Animals and is Returned to the Earth

THE PRIMAL MASTERY IN THE GREEN LEAF

If we are to understand the great issues involved in the coming conquest of disease, we must look at them not medically, still less medicinally, but biologically. So says modern science. And therefore we have to begin by looking at the age-long revolutions of what is often called the cycle of life. We must trace its parts in their order of succession and causation, if we are to see where what we call disease comes in, and if we are effectively to put a spoke in its wheel. The evolutionary or historical problem does not concern us here; it is enough for us to take the sequence of events as we can trace it now. If we follow what is, so to say, one complete revolution of the cycle, so that we come back to where we started, we shall see the world of life as a balanced whole, of which the parts are interdependent; and we shall also see the place where the great problems of disease arise.

We begin with sunlight, a form of energy which pours down upon the earth. No doubt life has a certain capital stored up in the earth, in such forms as coal or "buried sunshine." But the consumption of that capital is only a passing chapter in the history of life, and it was indeed accumulated in the very fashion which we are about to describe. The actual sunlight of the present is the income upon which Life lives; and if we trace the expenditure of Life's income, thus defined, we have all the main facts before us.

The existing life upon which the sunlight falls must somehow avail itself thereof. The first demand of all living things is food, and their food invariably includes carbon in some combustible form. Now, the air contains a quantity of carbon, in the form of carbonic acid gas, which occurs in the atmosphere to the extent of some four to six parts in ten thousand. But no animal, high or low, ancient or recent, can avail itself of this carbon; nor, if the carbon be given to it ready made, can the animal utilise it. If you eat a charcoal biscuit, or swallow a few diamonds, or enjoy coal out of the scuttle, as children occasionally do, you embody the carbon, but you do not employ it. Carbon in this form is of no use for the immediate purposes of life. If it is to start the cycle of life, it requires to be in the form of carbonic acid gas, CO_2, completely burnt carbon, which, as we have seen, no animal organism can employ, but which every animal organism produces, and must be rid of or die.

The green leaf alone has the mastery here. If we load it with carbon in the form of soot, as in any of our cities, it profits not at all, though carbon it wants and must have. Though it wants the carbon in order to burn or oxidise, the curious fact is that it cannot utilise unburnt carbon, but requires to go for it to the already burnt carbon we call carbonic acid. Now, this substance is a very powerful compound of carbon and oxygen. The respective atoms are united very firmly. The measure of this firmness is the amount of energy, in the form of light and heat, which is given out when carbon burns, and carbonic acid is produced. It follows that, if the chemist seeks to undo this combination, he requires to use a great quantity of energy for the purpose. In fact, he commonly finds that he can effect this dissociation, as it is called, of carbonic acid only at a temperature of thousands of degrees.

But the green leaf does it in the ordinary air of day, without sound or fuss, and it is in this dissociation of the carbonic acid of the air that the cycle of life starts rolling. The essential medium of the process is the green matter, called chlorophyll, which is characteristic of nearly the whole of the vegetable world. In some cases it is

replaced by a similar substance, yellower or browner, or even coppery in hue, but all are essentially the same, and have the same function. Chlorophyll is a transformer. It is not in itself a source of energy; on the contrary, chemical energy was spent by the plant in making its chlorophyll in the first place. But it has, in utterly unique degree, the power of transforming or directing certain parts of the energy of sunlight. The parts of the spectrum concerned are in especial those which lie near, and also beyond, the violet end. Thus in these "actinic," "chemical," "photographic" rays—which might, indeed, in virtue of their high function, be called *biogenic*, or life-begetting—and in their source, the sun, do we find an essential condition of earthly life as we know it.

How Light Aided by Chlorophyll Breaks Up Carbonic Acid

What, exactly, is the rôle of the chlorophyll in this dissociation of carbonic acid under the influence of sunlight? The energy required—as we saw the chemist requires energy for the same purpose—is that of the sunlight. The chlorophyll must be looked upon as a means of, so to say, focussing or directing the energy of the light, so as to produce the chemical result. Within recent years the chemists have been able to imitate this process, but "in a very feeble way," as Sir James Dewar himself says. The distinguished Professor at the Royal Institution was successful, somewhere about a decade ago, in decomposing the weak compound called iodoform—very different from the extremely strong compound which the green leaf decomposes—by simply passing electric light through it, free iodine being liberated. But though a poor parallel, it is a true one, a compound being dissociated by the actinic rays in electric light just as the carbonic acid is dissociated by the actinic rays of sunlight, but aided by the indispensable chlorophyll.

The History of an Atom of Liberated Carbon

At one time it seemed to the present writer that the chlorophyll acted somewhat like a ferment, causing a chemical change while being unchanged itself; but in conversation Sir James Dewar quickly convinced him that we can in no sense regard the chlorophyll as the active agent in this dissociation, but simply as the director of the agent, which is the actinic ray.

So much for the first stage of the cycle of life, in which man is merely an incident, as we shall see. Now let us trace further the history of the carbon thus obtained by the plant. If it simply remained as uncombined carbon it would be of no use to the vital processes of the plant, nor would it be of any use to us. We must observe that, simultaneously with this dissociation of the atmospheric carbonic acid, the plant is helping itself to water—not from the air, however.

It has begun to rain, let us imagine, and the leaves we look at are all dripping wet, yet not one is absorbing a single molecule of water. It is the function—one function—of the leaf, as of our skins, to give off water, not to take it in; and the process is known as transpiration. Hence the French word for "perspiration." The plant perspires or sweats by its leaves, thereby keeping itself cool, as we do, but it drinks only by its roots, just as we drink only by our mouths, and absorb no water from a bath. In both cases, the essential water cannot be taken in haphazard, anywhere, and anyhow, for it has a definite course to run, through the body of the living thing; and so its place of entry is limited, and its future doings are well defined.

The Absorption of Water to Combine with Liberated Carbon

In us, and in all animals, the water remains as water, and leaves the body as water, though in large degree with certain substances dissolved in it. But the green plant is very different in its chemistry, and can do what no animal organism can do, and without which no animal organism could exist. The water absorbed by the roots of the plant passes up the stem, against the pull of gravitation, by the plant's own elegant devices, until it reaches the leaf, where there awaits it, so to say, the carbon which has just been wrested from the air. The leaf is the living laboratory of the plant, and therefore of the animal. Somehow there the living protoplasm—no doubt by means of a ferment or ferments elaborated for the purpose—combines the carbon and the water so as to form certain substances which are appropriately called carbohydrates.

These substances, of high importance in chemistry and biology and dietetics, are distinguished in consisting of carbon and of hydrogen and oxygen in the proportions in which these occur in water. All the starches and sugars are carbohydrates. If we take a typical sugar, such as glucose, we find its "formula" to be $C_6H_{12}O_6$, the figures indicating the number of atoms of carbon, hydrogen, and oxygen respectively

that are combined to form a single molecule or unit of this sugar. Now, we might argue, from the look of this molecule, that it is really made up of six similar molecules, packed together, each having the formula CH_2O. But this is very interesting, for CH_2O obviously represents the simplest possible combination of a molecule of H_2O, or water, from the root, with an atom of C, or carbon, in the leaf, obtained from the CO_2, or carbonic acid, of the air. And there happens to be a substance having this very formula, CH_2O. It is known as formalin, or formic aldehyde, or formaldehyde, and is a very excellent antiseptic, in its place (which is not milk).

Solar Energy Gathered Up and Converted into Chemical Energy

And now our chemical sequence is complete in essentials. The first thing made in and by the leaf is formaldehyde, put together from carbon and water in the fashion just described; and we can see how this primitive carbohydrate, so to call it, is the antecedent of the sugar of the grape, since by packing six formalin molecules together, in some particular way which organic chemistry has not yet disclosed to us, we get the formula of glucose, or grape sugar. No doubt the chemistry of the carbohydrates is really very complex; and when we say that the general formula of the starches is $C_6H_{10}O_5$, or of certain sugars is $C_6H_{12}O_6$, or $C_{12}H_{22}O_{11}$, we have by no means adequately indicated the real complexity of the molecules of such substances, but the outline we have given states the essential facts.

The green leaf has now done its essential work. It has gathered in so much of life's income as fell upon it, and has converted that quantum of energy into the "chemical energy" of starch and sugar. Looking out from your railway-carriage window, you see the process going on in the green leaves of potatoes or wheat. In due course, the solar energy thus captured and transmuted will be eaten by the animal world—as, for instance, by any consumer of potatoes or bread—and the cycle of life proceeds on its course.

The Chemical Energy of Starch and Sugar Consumed from the Leaf to Support All Life

Every animal body in the world is thus supported. The animal may live directly upon the green plant, as vegetarians do, or may live upon an animal, such as the sheep or the ox, which has lived upon the plant. In any case, we consume the bodies and avail ourselves of the products of green plants—the vegetarian must perforce be, as Stevenson calls him, the "eater of the dumb." The whole of the animal world, from the humblest microscopic amœba r malaria parasite, up to and including man, is thus supported upon and by the green leaf. Without it, we should not be.

However, one must not say we *could* not be. For it is to be observed that there is nothing in this description, so far as we have gone, to negative the possibility that man may at any time reduce the number of stages and intermediaries in the processes by which he is fed, or by which any animals he cares for may be fed. At the present time, as throughout the past, the green leaf is essential, but we have insisted that it does not create. It only transforms. The energy whereby the whole animal world, like the whole vegetable world, lives is solar. There is no reason why, with more knowledge, man should not directly bring solar energy so to bear upon carbonic acid as to dissociate it, and even thereafter cause the carbon thus obtained to unite with water, and thence lead up to the carbohydrates.

The Passage of Carbon Back to the Air from Plant and Animal

But those who have looked closest into these processes are best aware of their difficulty. It is not as if soot or diamonds could be dropped into water, and formalin be the result, nor does chemistry find it exactly easy to construct starch or sugar out of formalin. Further, we are to observe that the animal world requires not merely the carbohydrates of the plant, but also its proteins, which the plant is able to make for itself, and which no animal can make. Thus, though there is no theoretical reason why man, having the solar energy at his disposal, should not be able, so to say, to "short-circuit" and run the solar energy directly into the making of compounds for his nourishment, yet for ages to come, in all probability, if not always, he will at least find that the laboratory of the leaf is better, more convenient, cheaper, more efficient, than any he can devise.

However that may be, we have now traced the carbon that was part of the atmosphere, now much transformed and combined, into the mouth of an animal, whence it passes to glands and muscles and brain and bone. Soon the greater part of it is there oxidised or burnt, thus yielding carbonic acid in the tissues, whence, by means of the blood and the lungs, in the

case of the higher animals, it returns to the air. In all animals whatsoever this is the necessary sequence of events—the carbon dissociated by the plant is again associated, and carbonic acid is restored, in its former form, to the air whence it came. Every expiration which punctuates the writing or the reading of these words is thus essentially the completion of what is called the carbon cycle—that part of the cycle of life which consists in the passage of carbon, derived from air, through the bodies of plant and animal in succession, and back to the air again.

The Lengthening or Shortening of the "Carbon Cycle" from Air Back to Air

Of course, the process may be delayed or shortened, and its number of stages may be various. The plant is not necessarily eaten by an animal; the plant itself breathes, and partly restores to the air the carbon it takes from the air. The animal which consumes the plant may be consumed by a second animal, and that by a third, such as man, who may in his turn be eaten by a cannibal, or a lion or a shark, but these details do not affect the essential sequence of events at all. In the long run, the carbon cycle is completed as we have described. Even the case of petrol, peat, coal, and other accumulations of carbon made by former vegetable life is only a kind of variant of the rule—animal life consumes vegetable products even so, and the atmosphere gets back its carbonic acid, even after millions of years.

Looking broadly at these facts, we must remind ourselves that the plant, or, rather, the green plant, is very definitely contrasted with the animal, in that the plant largely builds up what the animal largely destroys. The plant stays where it is, spends little, is thrifty, steadily accumulates, stores up, in the form of starch and sugar, the energy which falls upon it, so that instead of carbonic acid, which is in itself, so to say, finished, an end product, completely burnt and used, the plant provides us with compounds which can yield much energy.

The Spending by Active Animals of Energy Collected by Stationary Plants

The animal spends this energy, gadding about, doing things, and breaks down the steady upbuilding of the plant into the simple constituents with which the plant began. In the terms introduced by Sir Michael Foster, the great process of metabolism, or chemico-physical change, which is associated with all life, has an upward stage, anabolism, and a downward stage, katabolism; and it is the plant that is constructive, accumulative, anabolic, and the animal that is destructive, spendthrift, katabolic. Without what the plant saves, no animal could spend, and as the animal lives by spending, no animal could live.

In the foregoing we have specially described what we called the carbon cycle. But we might equally well have devoted ourselves to what may be called the nitrogen cycle. All protoplasm contains, and must contain, proteins, all of which contain nitrogen. No animal can use this element in its elementary state. The blood of every one of us contains quite a quantity of elementary nitrogen, absorbed from the air, of which it constitutes something like four-fifths; but we profit by it not at all. No doubt bio-chemical research has lately shown that the animal organism is capable of much more anabolism than used to be thought possible for it, but it can no more build up proteins than it can build up carbohydrates, though proteins, even more than carbohydrates, it must imperatively have, or die.

The Absorption of Nitrogen Through the Roots of Plants for a Nitrogen Cycle

Again, it lives upon the plant. What the animal needs the plant needs also. It must have proteins for its protoplasm, or die, and though it is exposed to the same nitrogenous atmosphere as the animal, it is similarly impotent to absorb nitrogen as such and utilise it. The sunlight and chlorophyll, which enable the plant to feed on the carbon in the carbonic acid of the air, do not avail it for the nitrogen. We must turn from the plant's leaves to its roots, where we saw it absorbing water. In the soil there are compounds of nitrogen which the plant can use. We call them inorganic compounds of nitrogen—such things as ammonia and its salts, and nitrates of various metals—and we can prove that the plant absorbs them. No animal can utilise these compounds and build them up into proteins, any more than it can use the free nitrogen of the air. But the anabolic, constructive plant can take these simple salts, and can build them up into proteins.

As to how this is done, or the stages in the doing of it, we must confess ourselves wholly ignorant. In the case of carbon we were able to form a very fair mental picture of the meeting of carbon and water, the construction of a sort of very simple carbohydrate and its elaboration. But to trace an ammonium salt or a nitrate

upwards to a protein is entirely beyond our present powers. The complexity of the problem may be realised when we learn that carbohydrates are themselves but details in the composition of a protein; as we know from the fact that when proteins break down carbohydrates appear, as in the production of sugar from the proteins of the body in the disease called diabetes. We cannot yet expect, therefore, to trace the nitrogen in its anabolic course, from a mere nitrate up to the most complicated compounds known to chemistry, which the proteins are. But the fact of this ascent remains, and the further fact that no animal organism can contrive it, though no animal organism can do without its products.

The Resting of the Animal World on the Plant World, Through the Nitrogen Cycle

Again we find the animal world resting upon the vegetable world. But recent inquiry has shown that the nitrogen cycle is really very much more complicated than the carbon cycle. For we now know that many green plants are aided in their anabolic work by the services of certain *not* green plants, bacteria, as they are called, which live in the soil, often attached to the roots of the green plant, and have the power of fixing the nitrogen in the soil air, and turning it into salts, which the roots can then absorb.

That is a very remarkable story, for it gives to certain bacteria a high place in the sequence or cycle of life. They help to make the bread by which we live. As Mr. Hall and Dr. Russell have shown, further complications arise, for minute animal organisms live in the soil, and are liable to consume some of these useful bacteria. That is no concern of ours here, except in so far as it serves to illustrate further for us the complexity and the interdependence of processes and persons concerned in the balance of Nature and the cycle of life. Even Darwin's most fascinating illustrations become simple and unimportant compared with what the microscope has since revealed.

The Help Given by the Bacteria of Putrefaction in Releasing Animal Constituents

But the cycle is still far from complete, even though we observe the excretions of the animal, such as carbonic acid, and observe their identity with our starting-point. The individual animal dies. It may have a living tomb in the body of some carnivore. It may be burnt, and thus at once reduced to simple substances, such as carbonic acid and water. But the normal typical destiny of the animal body, sooner or later, is to sink into the soil. If it so remained, the continuance of life would soon be impossible, the cycle of life would have to stop rolling. But that is not so, for the soil, we remember, is the environment of the roots of the green plant, and provides it with food. Once already we have seen bacteria play a useful part; and now we learn of more essential uses still. The "nitrefying bacteria," as they are called, which fix the atmospheric nitrogen, are but a subsidiary group, valuable though they be. Essential, however, for the continuance of life are the ordinary bacteria of putrefaction which abound everywhere, but pre-eminently in the presence of animal or vegetable matter from which the life has departed.

Again and again we have spoken of the plant and the part it plays in the maintenance of the animal world. But we always meant that great anabolic, constructive agent, the green plant. Now we encounter, with a full sense of its importance, a sub-division of the plant world, of which the very existence was unknown until the nineteenth century.

The Special Position of Plants that Have No Chlorophyll

All plants whatsoever which are destitute of chlorophyll are called fungi. Their deficiency compels them to live, not as all green plants do, but as all animals do, by destruction or katabolism, instead of construction or anabolism. We call them plants because we cannot call them animals, and for some other reasons, but they are practically, and as regards their place in the cycle of life, a kingdom apart.

The lack of chlorophyll, with the dietetic necessity which that imposes—for the plant cannot feed on air, cannot live by energy of sunlight, and must therefore get that energy indirectly from plants which can, as animals must—puts the mushroom or the toadstool and the invisible fungi in one and the same class. The invisible ones are immeasurably the more important. When the microscope makes them visible, we see that they divide and multiply by splitting, and we therefore call them the fission-fungi, or schizomycetes. They are commonly longer than they are broad, and we call them bacteria, and the study of them bacteriology. They may be quite rod-shaped, and we call them bacilli; or round, and we call them cocci, but bacteria is to be understood as the general name. All bacilli are bacteria, but only bacteria of a certain shape are bacilli.

Really, the shape is nothing, but the habits are everything. In brief, we may say that, normally, originally, properly, bacteria live upon *dead* organic matter. It must be organic matter, made by pre-existing life, because the bacterium, being without chlorophyll, cannot use sunlight in order to build up organic compounds for itself from inorganic materials. The technical name for a bacterium (or for any fungus, of course) that lives upon dead organic matter is a saprophyte, and such an organism is said to be saprophytic. The name is not pretty, and the mode of life is not beautiful, nor do our noses commonly appreciate some subsidiary results of the process. But without it neither we nor our noses should be here.

The Scavengers of the World that Break Down the Bodies of the Dead

Let us leave aside the special uses of the saprophytic bacteria—their services in the curing of tobacco, the tanning of leather, the making of synthetic rubber, and a thousand other processes which depend upon their powers as ferments. Those uses daily increase in number and importance; and people are gradually coming to realise that there are useful bacteria, which can be put in harness for human purposes. But all these uses are entirely trivial compared with the universal and essential business which the bacteria as a whole perform—the breaking down of the bodies of the dead. Without this agency and these agents, the cycle of life could not be maintained in motion. Frequently we hear it stated that the bacteria of putrefaction are the scavengers of the world, clearing away offensive matter. But in fact they make it "offensive," as we call it. Without them it would be quite innocuous to our senses, and would simply remain as it is. The bodies of the dead would not decompose or rot. They would simply accumulate.

Bringing Back to the Earth Nitrates for Future Use

The function discharged by the bacteria is to make the bodies of the dead available for the purposes of the living. They set to work, with their sharp, invisible teeth, which we call ferments, to tear to pieces and disintegrate those elaborate compounds, from the proteins downwards, which they find in the bodies of animals and plants alike, and the history of which we have traced. This is not the choice of the bacteria, but their necessity. Their lack of chlorophyll compels them to be saprophytic. Possibly they are to be classed as degenerate, and as having fallen from the higher state of such simple green plants as the algæ. No doubt their processes are simple, and their personal development very limited, but they make us possible.

The animal body, high or low, no matter whom or what it housed, dies and returns to the dust. The microbes of putrefaction resolve it into sulphates, phosphates, nitrates, and so forth, of various metals—calcium, sodium, potassium, in especial. Now, we said a little while ago that "in the soil there are compounds of nitrogen which the plant can use." A fair question, then, would have been—Whence do they come? Here we have the answer. They come from the bodies of the dead. The cycle of life is complete. No doubt every species lives for itself, seeking to realise and amplify and intensify life along its own lines. No doubt, as Darwin said, there is no case of any species having any characteristic evolved for the purposes of another. But they are all one, nevertheless. As we dwell, we living things, in this our "isle of terror," each of us is inalienably bound to all the rest. So you may be selfish for a century, but at last others will claim your dust. The whole creation groaneth and travaileth together.

How the Invention of the Motor-Car May Save the Lives of Many Infants

At every point Life tries to assert itself; it does so in the living, and then avails itself of them, in another way, the moment they are dead. And though the struggle for existence seems internecine, it is really the shortest way to the most life; and the lowest of the forms which compete in it may be found indispensable for the existence of the highest.

Two large conclusions emerge from this study. The first has often been pointed out, and still more often illustrated. It is that human interference with living forms must necessarily have far larger consequences than will at first sight appear. We see some kind of creature living somewhere—somehow, as to which we do not think—and we exterminate it. We want to eat it, or it is dangerous, or it is interesting to hunt. On the other hand, we like a species, and we introduce it into a new habitat. But only critical inquiry, in each individual case, and not always even that, can set a limit to the consequences in terms of the survival or disappearance of *other* species, which may be indefinitely remote in the scale of Nature.

Flies breed in and feed upon the refuse of horses. The bacteria engaged in breaking down the refuse are carried by the flies into

houses, reach babies' mouths, and kill them, like flies, every summer. The invention of the internal combustion engine and the slow disappearance of the horse from cities thus directly leads to the increase of surviving babies. This is a mere instance, quoted because it happens to be recent. It is a favourable one, but that is mere accident. In many other cases, man disturbs the balance of Nature having no conception of such a thing, and the results are disastrous. We should undoubtedly walk more warily and wisely in these matters if we had any adequate conception of what is here called the cycle of life.

Microbes Good and Bad—Indispensable and Injurious

Secondly, we learn once and for all that we cannot do without bacteria or microbes, as Pasteur called them. Essentially, primarily, originally, they are to be looked upon as beneficent. Yet we all know not only that some of them cause disease, but that they cause nearly all disease. Clearly we require some sharp distinctions here. A special name is easily made for disease-producing microbes; we call them pathogenic. And what constitutes their "pathogenicity"?

The typical microbe, we said, is a saprophyte. It feeds upon organic matter which is dead—was alive, but is not. Such a microbe can do no harm—does indispensable good. But other microbes, as to which we may confidently say that they are historically, evolutionally derived from the saprophytes, feed upon the tissues of the living. These we call parasites, and the two contrasted terms must be most definitely understood, and used with accuracy. No doubt there are some saprophytes which can become parasitic on occasion, and some parasites which can become saprophytic, as when the bacteriologist cultivates pathogenic microbes in beef-jelly or milk. Such forms require to have a very close eye kept upon them, plainly; and what we already know of them, so far from minimising the distinction between a saprophyte and a parasite, only tends to emphasise its importance.

The Advent of Disease to the Great Cycle of Life

We have everything to learn about the transition, above all in the dangerous direction. Thus, our bodies harbour microbes which commonly do us no harm that can be defined. Probably they live as saprophytes, strictly speaking, though we are alive, because they merely consume lifeless materials in our food. But at times these organisms may become pathogenic, perhaps setting up appendicitis. It may be that the saprophytic microbe has now become parasitic, attacking the living cells that line the bowel, instead of merely the lifeless food within it. The distinction here becomes a matter of life and death; and appendicitis will be a preventable and prevented disease from that day on which we can define the factors which turn a saprophyte into a parasite in this instance.

We see, then, where in the cycle of life the possibility of disease arises. It is at that point where the saprophytes are needed to keep the cycle going. They may exceed their functions—attack the living as well as the dead, and that is disease. In due course we shall see that not only fungi, by any means, are parasitic. Far from it, indeed. But the fungi are by far the most important of all parasites, and their place and origin in the natural order has now been defined.

Only one other point needs insistence. It is that there is no more vice or malice or mortal intent in the activity of a parasitic than of a saprophytic microbe. It is merely trying to live as much as possible. Only it may so happen that the requirements and products of its life are antagonistic to the requirements and products of its host.

Various Forms of Parasitic Disease—Harmful and Negative

This is not even necessarily so. On the contrary, many parasites are not pathogenic. They manage to live at the expense of their host, but without injuring him, so far as we can see, for in some way or other he protects himself. And, further, the "success" of the pathogenic parasite is disastrous to it, for where its host is killed by it, its own fate is sealed. Thus we must beware of applying moral judgments to these problems. In fact, they all illustrate Life in various forms doing the best for itself. Only, the process at every turn provides warrant and precedent for what the species we belong to must do for itself, as all the others do for themselves. We must kill these parasites in the interests of our lives; and though our bodies do so with much success, the time has come when we must bring our minds to their aid, and so achieve the prophecy of the pioneer whom we shall shortly study: "Make all parasitic diseases disappear from the world."

Success in the discovery of harmful parasites, and the means of counteracting them, make it by no means an impracticable vision that some of the worst diseases which have scourged mankind may be finally extirpated.


WIND-BORNE-SEEDS OF THE DANDELION


FLOATING SEEDS OF THE CARBINE THISTLE


WIND-DISTRIBUTION OF THE SEEDS OF THE HAWKWEED

HOW PLANTS ARE SPREAD

The Arrangements Whereby Stationary Growths Prevent Overcrowding by Dispatching Their Seeds to a Distance

UNCONSCIOUS SERVANTS OF PLANTS

We now come to the consideration of one of the most interesting aspects of the life of plants—namely, that of their distribution in the world, or, as it is termed, plant geography. The specialisation of function for various definite purposes is nowhere better exemplified than in plants, and we have already studied some of the physiological processes which are carried out by means of special devices. The dispersal of plants over the surface of the earth is another of these definite objects which plant life has to manage in order to survive; and it is almost more necessary to plants than to animals that special means of attaining this end should be developed, for the simple reason that the majority of plants have a definite fixed position in which they grow. All of the higher animals are provided with organs of locomotion; and in their case specialisation of these organs, when it occurs, is directed rather to increasing the speed of their movement, as we find in the wings of birds, and in the limbs of an animal such as the deer.

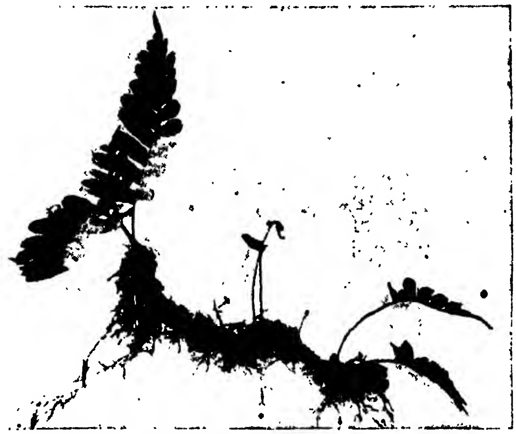
But although we usually regard plants as living creatures in a fixed habitat, a moment's thought will show us that unless the plant is provided with some means which will permit of its *offspring*, at least, being transported to some distance, it could not possibly survive as a species; or, at least, it could never increase very much in number. It would be in the same position as a human community—restricted either by geographical or other limitations within a given area, beyond which, no matter how great the increase in the population, the individuals could not go. The inevitable result would be that, as soon as the individuals reached the number which was the greatest that could be carried by the area in which they lived, every single individual above that number would either be starved for lack of food or would otherwise perish in the struggle for existence. This actual process occurs in nations, which therefore require, as an urgent necessity, colonies or dependencies for their surplus population.

So it is with plants. A very few generations in plant life would bring about such a congestion and crowding in the immediate vicinity of the parent plants that no more could survive unless Nature provided some means of dispersal for the younger generations. The necessity is so urgent that we no longer wonder, once we have recognised it, that the variety of means which have been evolved in plants to attain this end is almost infinite. To some of the more striking of these adaptative arrangements we may now turn our attention.

Among the cryptogams, those lowly plants whose organs of fructification are concealed, or not visible, a very common means of propagation is by means of spreading roots, which travel along underground considerable distances, and so extend their area of living. This is seen in the ferns. But most of these flowerless plants reproduce themselves by some sporing arrangement in which the actual spore itself is so minute an object that it is carried with the greatest of ease by even very slight movements in the air, and, of course, with still greater ease by moving water. The distance to which such spores may be transported from their original home can hardly be estimated. Doubtless there is nothing to prevent the contents of the ripe puff-ball—full of fine, powdery spores—from travelling over a whole continent in the air, or even traversing a mighty ocean in a storm of wind; while as for the spores of the marine plants themselves, their limit of distribution is

only to be gauged by that of the ocean currents themselves. All that is necessary is that the living principle in the spore be protected sufficiently in order to survive the journey.

We have seen in an earlier chapter that certain plants propagate themselves, amongst other means, by runners, or root-stalks, and this is another way in which the plant may gradually come to spread over quite a considerable area. Then, in a somewhat analogous way, we have the spreading of the roots underground, and the sending up of shoots at intervals, as is seen in the case of trees like the silver-leaf poplar, which may do great damage on lawns by the number of shoots that spring up from underground roots coming from a distant tree. In a state of wild Nature such trees as this silver-leaf poplar depend upon this method of securing a wide enough area to maintain the species.



CREEPING ROOT OF POLYPODIUM VULGARE

A more unusual and very striking method of gaining the same end is for the branches of a tree itself to grow towards the earth, and on reaching it to strike root. This is, of course, only an exaggeration of the process of the runner, as seen in the strawberry. But it looks the more odd to see a large branch hanging freely from a considerable elevation, and then striking root. But branches may aid in distribution by dropping off the tree altogether, and being carried either by wind or water to some considerable distance, where again, roots quickly appear from the broken end of the branch. Some of the willows exemplify this process extremely well.

THE UNDERGROUND ROOT-SPREAD OF GRASS ON A SAND DUNE

Then we have the large subject of the dispersal of seeds themselves by different mechanisms on the part of the plant, some of which we shall have to study almost immediately. But far more commonly than by a special mechanism are seeds spread by external agencies, particularly wind, water, and animals, and artificial means of communication between places and countries wide apart. Occasionally the transport of the seed is materially aided by the living principle being enclosed within a hard fruit structure. Sometimes, however, it is the seed itself which is so modified as to help its own progress. But all these arrangements, no matter how diversified they may be, have the same object—namely, to avoid overcrowding of individuals in one district.

Another very curious arrangement for this purpose is seen in such fruits as, when ripe and dry, burst open with a considerable degree of force, and throw the seeds some distance. This process is sometimes attended by quite an audible noise.

Then we have fruits and seeds in considerable number that may be termed *winged*, because of the remarkable membrane-like wing attached to the seed, which serves the purpose of sails to it, and by means of which its dispersal is aided. Examples of this particularly interesting, though quite common, type of seed-dispersal are seen in the sycamore, the ash, the elm, the maple, and other trees, those of the sycamore being figured on page 2849. Still others have exquisite little tufts of fine hair attached to the seeds.

When set free into the air the seeds are carried by currents of wind to immense distances by the hairs acting as the sails of a ship.

This arrangement is one of the most perfectly successful of the means for dispersal, as may be gathered from the observations of the number of thistles and dandelions that spring up in any district where these plants are allowed to mature. Both of them produce these tufted seeds in great numbers, as do many other plants, and consequently their distribution is world-wide. Another arrangement is that of certain plants which, when dried up, are easily blown about over the surface of the ground, and drop a few seeds here and there as they go. The more rounded in form such a plant is, and the lighter in structure, the better will it carry out its mission.

A RIPE BULRUSH AND ITS SHED SEEDS

MOSS SPORES CAST TO THE WINDS

From a highly magnified photograph

An exquisitely ingenious arrangement is seen in the capsule of the common poppy, which is practically constructed on the same principle as a pepper-pot. Within the capsule in the poppy an immense number of minute seeds is produced, and when the period of maturity arrives these are shed in small quantities at a time through apertures that allow only a certain number to emerge at once. Very similar arrangements are seen in the monkshood and the larkspur.

It is difficult to estimate the importance of water in plant distribution, but anyone who will take the trouble to collect a number of the fruits and seeds of plants and place them in a pan of water, will be surprised to observe how large a proportion will float. Still more interesting is it to leave them for a day or two, and notice what proportion will still remain on the surface of the water. In this way it is brought home to one that water-carrying must be a very important means of seed-dispersal.

One of the best known of these water-travellers is the cocoanut palm. It has been estimated in some cases that the seeds of this palm have found a new home by floating more than a thousand miles uninjured. An examination of the fruit shows how easily this might happen. Quite a large number of species of plants are known to disperse themselves by thus drifting in currents of water.

Then many plants have evolved arrangements by means of which any passer-by, be he man or beast, is compelled, willingly or unwillingly, to assist in their distribution. Everyone is familiar with the burrs which adhere to one's clothes after a walk in the country at a certain time of the year. These outgrowths take the form of hooks of some sort or other; and so effective is their strength of attachment that it is hardly possible to get them out of the hair or wool of cattle and sheep without actually cutting the hair with

them. A very interesting case is quoted by Mr. Bergen, of Boston, U.S.A., in this connection. A buffalo, whose hair was full of some fruits of a peculiar kind of grass, was sent as a present to a leading personage on the island of Ternate, in the Malay Archipelago. This particular kind of grass, hitherto absent, rapidly spread over the whole island as the result of this method of introduction.

Then, of course, we have the whole army of stone-fruits and fleshy fruits to consider in this connection, because most of these being eaten, either by man himself or other animals with more or less similar tastes, are naturally very important means of scattering the seed within the fruit. It is worth noting, in passing, that evidently the deliciousness of these fleshy fruits has been evolved quite definitely for the special purpose of scattering the seeds. Plants do not evolve structures for the benefit of any living thing but themselves; and therefore one can only imagine that the reason why the pulp of so many fruits is eatable and palatable is to form an attraction to some fruit-feeder, as the result of which, having satisfied his own palate, he will drop the seed at a distance from where he gathered the fruit. Evidently for the same reason the covering of the actual seed itself in many of these fleshy fruits is much too hard to be either changed during mastication or digested if swallowed; and such seeds, being carried within the bodies of animals, are ultimately scattered abroad with the excrement of the creature. In this category come such fruits as the fig and the currant, whilst in the former we may mention the peach and the date.

In the cases just mentioned, from the sticky burr to the swallowed currant-seed, the part played by the animal was either unconscious or, at any rate, not deliberate. But there are other instances in which animals purposely carry about seeds, probably in order to store them up for future food. When this happens it is usually the fleshy part of the whole fruit that is devoured, and the actual seed, which contains the embryo, is left. So ants carry away seeds thus provided with a fleshy covering, and some of these seeds appear to be constructed as if of set purpose for the ant to handle. Similarly, too, our squirrels store up nuts and acorns in different places as a provision for winter food, but quite frequently they forget where they have put them, and thus become unconscious scatterers of the seed itself.

A still further refinement of a similar adaptive plan is seen in succulent fleshy fruits extremely bitter to the taste until such time as the true seed is ripe within. Then they become attractive to the animals that play the part of distributing agents. The orange is a case in point.

GOOSE-GRASS BURR

THE BATHURST BURR

THE HOOKED AVENS SEED

From the foregoing preliminary statement as to the chief methods adopted by plants to disperse themselves, it will be realised that foremost among these methods must be placed those which either in one way or another have reference to the disposal of the fruit. We may therefore at this point pay a little attention to the fruit of plants strictly from this point of view, reserving to a future occasion other interesting aspects in the study of fruits.

The fruit arises from the flower of a plant after the process known as fertilisation is completely finished. It will be enough if we realise at this stage that a pollen grain

unites with an egg-cell inside the ovule, as the result of which the ovule itself gives rise to a seed. Now, the term "fruit," in popular language, often means a great deal more than the mere seed itself. In fact, we speak of fruit in reference to quite other parts of plants than those included in the strict botanical sense of that word. For example, we refer to the strawberry as a fruit, whereas the fruit of the strawberry consists of the small, dry little seeds scattered over the surface of what is popularly called the fruit.

In the same way the fruit of the apple, in the sense in which we used the word in common language, is the very much enlarged receptacle of the flower, the true fruit, of course, being the core. So with other examples in great variety, leading us to the conclusion that fruits, in the botanical sense of the word, are indeed of many kinds. And, according to the nature of the fruit itself or its covering, so is the arrangement for its dispersal different.

WOOL CONTAINING VARIOUS HOOKED SEEDS

Some of the coverings of the true fruit, when they attain full ripeness, open with a spring-like movement, sudden in its onset, having more or less explosive force, as it were, sufficient to scatter the seed to a distance of two or three feet from the plant. This mode of dispersal may be seen in many of the ripe pods of the leguminous plants, such as the peas and beans. In them it may be observed that, after the pods have burst, the valves within them quickly twist themselves up.

But inasmuch as the wind and currents of air are the most potent factors in the dispersal of seed, it is natural to find that the great majority are sufficiently small in size and light in weight to be easily carried for a considerable distance in the wind. There are, however, special adaptations to assist in this process. For one thing, many seeds are quite round in shape, which enables them to be easily moved along a sufficiently smooth surface by any propelling force acting as wind does. More effective and more striking are the special structures frequently found attached to the seed, which enable it to sail through the air more or less like a parachute. We have already referred incidentally to the clump of fine hairs acting in this way in connection with the thistle and the dandelion and groundsel. The seeds of these plants, by means of the modification mentioned, are enabled to spread themselves over immense areas of ground, and to be carried for enormous distances.

Very remarkable, too, are the structures, looking like wings, which are seen in the case of the seeds in the ash, the elm, the sycamore, and similar plants. The seed in these cases is a fairly heavy structure, and if allowed to fall will do so almost vertically, even though its wings cause it to flutter But if we watch what happens we shall observe that these fruits, or seeds, are only detached from the trees when the wind is of a very considerable velocity or force. Then the wing-like apparatus with which they are furnished assists in their being carried through the air for a long distance.

A peculiar modification applying to the part played by water in seed-dispersal is seen in the case of the plants which develop a sort of buoy, that encloses a sufficient quantity of air to cause the whole thing to float. This buoy encloses, in addition, the seed, and in this way it is carried wherever the current of water goes.

With regard to the part played by animals, too, we find in many of the umbelliferous plants, such as the carrot, special structures in the form of spines, or hooks, that cause the seeds to adhere very readily to the covering of any animal they come in contact with. Ultimately, they are rubbed off the animal's coat, often at a considerable distance from their place of origin

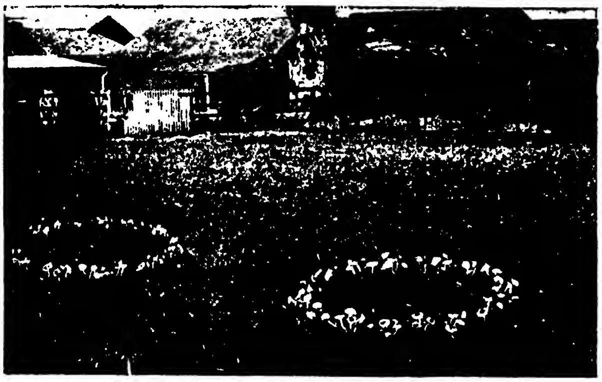
We have already referred to the dispersal by animals of the seeds which lie within the fruits they eat, these seeds passing through the alimentary tract of the body without being injured. This involves some special form of protection against the digestion of the embryo within the animal's stomach. So we find that in these cases there is a very hard, dense pericarp, or fruit-covering, formed from the coats of the seed. This structure, the pericarp, is sometimes the attractive portion to the animal. For instance, in the group of berries, like the cherry and the plum and so forth, the pericarp itself forms the attraction to the animal.

In what we popularly speak of as the stone-fruits, there is a hard covering within, the endocarp, which quite effectively prevents any digestive process injuring the seeds while in the body of an animal. These firm, hard coverings will persist for a very long period of time, enabling the seed to be preserved until chance, or design, brings it into such an environment as stimulates it into new growth. Then the protective coverings disintegrate, and the embryo, having passed unscathed through winds and waters, and even animal bodies, is enabled to bring forth a new individual, possibly thousands of miles from the spot where the fruit was produced.

So much for a general consideration of plant dispersal, but now we must consider in detail some of the more interesting special examples of the modifications which play a part in securing this end.

An interesting arrangement of the spread of some lowly plants is that seen in connection with the formation of what are spoken of as fairy rings. These occur frequently in meadows and under trees. Some of the fungi produce very picturesque results. The first growth in the region of the ring is that of one of the fungi themselves. This dies down in due course, as do the plants whose roots have been penetrated by the threads of the fungus, leaving a sort of brown ring. In subsequent years however, this merely forms manure for fresh plants, which therefore grow in this circular manner more luxuriantly than before. The original fungus is all the time moving outwards in a larger and larger circle, and so the ring gets bigger. Country folks used to associate these ring-like patches with the dances of fairies, or elves, or witches, and popular superstition in some countries attributes their origin to dances by the fairy folk on the night of the 1st of May.

Other fairy rings are formed by plants which send forth underground runners, the growth dying in the middle, but extending peripherally. Thus, distribution of plants by offshoots frequently produces an area of distribution of a circular shape, becoming larger and larger. Of course, it is necessary that the original plant should die, that its growing points should radiate outwards, and that the successive plants should also die, leaving only the living ones at the circumference.



FUNGUS FORMING FAIRY RINGS

Just as some plants distribute themselves in circles, so do others in more or less straight lines; and this latter formation is the result principally of roots that run horizontally under the soil, and give off buds at intervals. The long connecting root dies here and there, leaving these new individual plants growing more or less in a straight line. The raspberry is a plant which conforms somewhat to this arrangement. A group of raspberry plants moves about three or four feet every year; and so it often happens that raspberries planted near a hedge or fence may, in the course of a few years, be growing quite well on the other side of the fence (possibly owned by someone else), while the original plants have entirely died out.

Dispersal by means of underground tubers is sometimes wonderfully fast, and gives rise to quite large colonies, which gradually spread over a larger and larger area. This sort of process is seen in the artichoke, whose colonies may be regarded as being arranged in clusters. The rapidity of the spread in such cases as this will depend

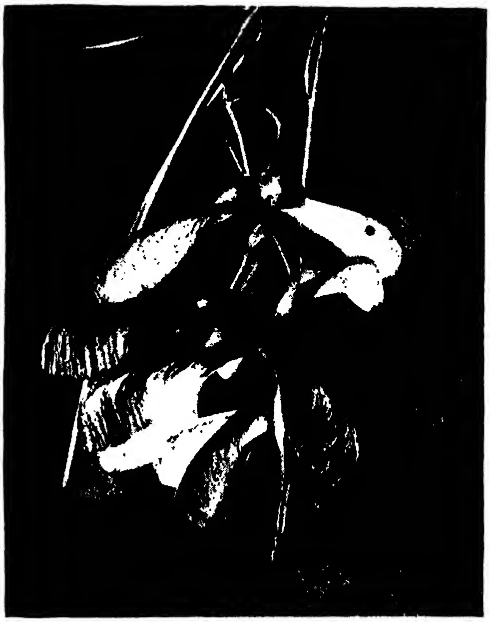
upon the length of the underground growth, and the nature of the soil.

The extraordinary rapidity of the dispersal of a plant over an area of ground by means of offshoots on runners is best seen in the strawberry, as described by Kerner.

"Suppose a strawberry stock sends out three runners during the summer: each takes root at five nodes, and from each node a bud—*i.e.*, an offshoot—develops, so that the following year the mother-stock is surrounded by fifteen daughter-plants. It should be noted that the length of the internodes in each runner is unequal. For example, in one which had extended over the ground in the shade of the wood, the first internode was 37, the second 34, the third 31, the fourth 30, and the fifth and last 22 cm.; thus the offshoots were the closer together the greater their distance from the mother-plant. Next summer fifteen new offshoots were again formed from each of the original fifteen, arranged in exactly the same way; and in the forest glade, where two years previously there had been only a single strawberry plant, occupying a space of 50 sq. cm., there would now be 200 plants distributed over a space of about 3600 sq. cm."

ALGÆ SPORES SCATTERED IN THE SEA

Of course, when plants change their position merely by sending out offshoots in one direction or another, while they themselves die in an opposite direction, the actual range of distribution is naturally restricted. It is, however, very much increased when we have to deal with plants whose offshoots become separated from the parent stalk, and can be transferred by any of the agencies of wind, water, or animals to fresh pastures. In this way the range of



THE WINGED SEEDS OF SYCAMORE

distribution of a plant may be extended in a very few minutes over an area which would take many years to cover by ordinary runners. On the other hand, it is not so certain a means of survival, because the detached offshoot may land in an unsuitable environment, but, considering the number of shoots provided for such a purpose, the object is usually successfully attained.

Very few plants produce special organs which enable their shoots to move about on their own account, and when these do occur it is only in the lowly plants which inhabit water. Many, however, are carried passively by water, such as the green algæ, those slimy masses we often see on a sluggish pool, or covering the surface of submerged stones. These plants detach portions of themselves freely, and each portion starts a new growth in a new place. No simpler means of distribution could be conceived.

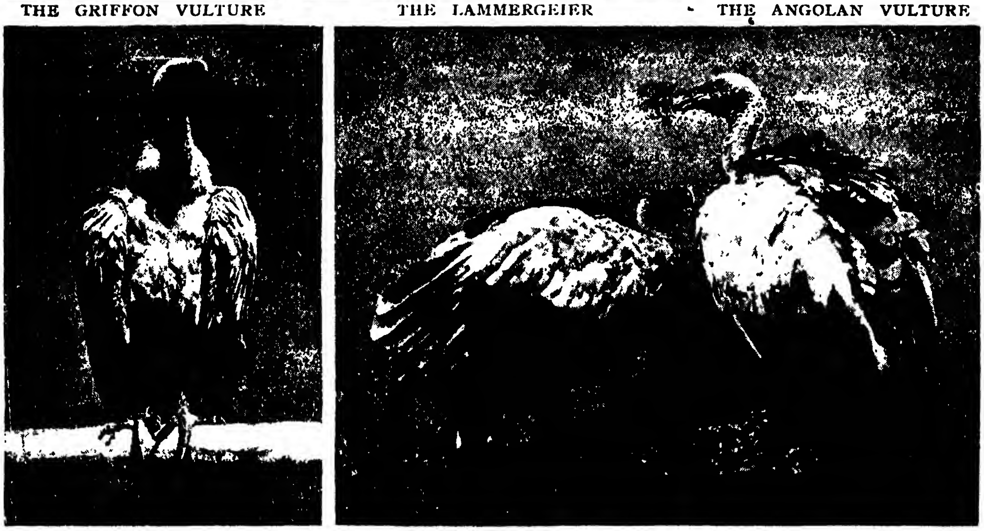
The seaweeds, and similar plants, appear to owe their distribution mainly to the force of circumstances. Portions of them are torn asunder during the high tides and rough weather, and carried hither and thither until they are deposited into spaces between rocks and stones, or in sand, where a large proportion of them starts fresh growth.

SCAVENGERS OF SUN-SMITTEN LANDS

THE GRIFFON VULTURE

THE LAMMERGEIER

THE ANGOLAN VULTURE



KOLBE'S VULTURES FROM THREE DIFFERENT POINTS OF VIEW

THE TURKEY-VULTURE

RUPPELL'S VULTURE

THE PONDICHERRY VULTURE

CONTRASTS IN FLIGHT

The Magnificent Kings of the Air, and the Birds which Do Not Fly at all

THE BIRD OF PREY AS A TRAINED HUNTER

Consider the eagle and the penguin. In the eagle, flight attains a power and majesty unexcelled; in the penguin it is impossible. The penguin waddles on land, rows upon and under the water, and can no more fly than an ostrich. The eagle, and the predaceous tribe of which he is typical, are undeniably an excellent example of evolution. But the hapless penguin and the flightless running birds, what of these? Are the wings of the penguin degenerate organs?

It is customary to answer unhesitatingly in the affirmative. The common belief of modern naturalists is that the first birds were denizens of the trees, in which they crawled and clawed their way about in manner resembling the reptiles from whose form and order they were departing. That being so, we rapturously acclaim the hoatzin as the living link between contemporary birds and the birds that were hardly birds at all. For the young of this singular South American bird is furnished with well-defined claws to the thumb and forefinger; and by the aid of these and of its beak the almost naked nestling climbs about the branches in which its nest is placed, very much as the first of arboreal birds must have climbed. The "fingers" of the wings are the last of the bird's body to become feathered, for the young hoatzin climbs until it can fly—climbs and swims: for when it falls or chooses to dive from the bough, it makes its way as readily as a duck through the water. The adult bird does not climb; it flies indifferently, and seldom comes to earth; and it does not swim, while the claws gradually disappear with the coming of the flight-feathers proper.

Here, then, we see the story of the beginning of flight retold with every hoatzin that is hatched. If the deduction be correct, if all flying birds did begin their career in this manner, then obviously the attenuated paddle of the penguin must be the result of disuse, degeneration brought about by the bird's neglecting to employ its wings as instruments with which to cleave the air. That is the commonly accepted theory. But there is another. There persists a theory that the first bird was aquatic, evolved from an aquatic reptilian ancestor, and that the first wing was a true paddle. Sir Ray Lankester is among those who deem this view still capable of defence. If there be anything in it, then the penguin may not be degenerate, but primitive; its paddle-wing may be rudimentary, and not a vestige of a true wing become degenerate. We all regarded the marsupials as the ancestral form of mammals, but the evidence of today makes it almost certain that the pouched mammal is simply a degenerate placental. It would be strange indeed should the penguin restore the balance, as it were, by proving a primitive rather than a degenerate bird. It is a pretty problem, and, having stated its terms, we must leave it there, and consider in detail certain birds, chosen for the purpose of contrast, superb fliers like the larger sea-birds, the birds of prey; the ostriches and their like, and the veritable penguins.

There could scarcely be a more complete contrast than that between the albatross and the penguin, both pelagic birds, the former the largest of the feathered haunters of the deep, the latter the largest of ocean swimmers. The albatross, whose food resembles that of ocean-going birds with which we are already acquainted, is undoubtedly one of the most remarkable of all flying birds. With its enormous stretch of narrow wing, and its infinite skill in taking advantage of every wind that blows, it keeps the air so long that grave and cautious writers have declared that it can hang in the air for days at a time without once moving its wings. It is true that the albatross "sails" longer

than any other bird, but if we could cinematograph it we should find that in order to perform those long glides it requires momentum and driving force, even as the aeroplane does. The quickness of the wing, like that of the conjurer's hand, deceives the eye when the bird is at a height. When the albatross is on a level with the eye it can be seen, every now and again, to give a few powerful strokes with the wing, so gaining momentum enabling it to glide like a living kite into the wind, or with it.

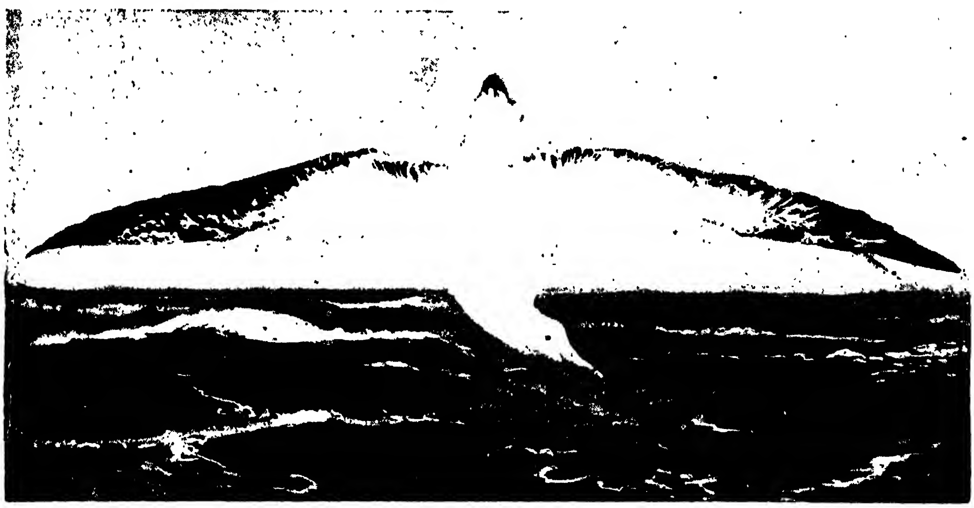
The albatross works for his livelihood, but another famous flier, the beautiful frigate-bird, loafs throughout the day; then, darting out from the shelter of an oceanic island in the evening, attacks terns and gannets and other sea-birds, and causes them to disgorge the fish that they have caught. The frigate-bird can catch fish for itself, snatching them from the surface of of the waves, but the bird never dives into the water after them.

The tropic-bird, which is found in the same latitude, is another superb airman, and, like the albatross—which will follow a fast-steaming vessel for hundreds of miles, circling round and round it in great sweeps, so that its journey becomes one immeasurably greater than that of the vessel—the tropic-bird keeps ocean-going craft company for long at sea, to snap up the unconsidered trifles cast overboard.

A better diver, because more practised than the frigate-bird, is the bold and handsome osprey. This flying fisher, externally resembling the hawk tribe, is found to be more nearly related to the owls than to the hawks, but so related less by blood affinity than by what is known as convergence. The osprey, which was once common in Scotland, but is to be met now as a rule only as a rare summer visitor, catches its fish in sea or river, and always by the same method, pausing in its graceful, elegant flight to swoop down upon the surface of the water and wrest thence some fish its splendid vision has detected, or even plunging some short distance beneath the waves to complete a chase ineffective at the crest of the wave. The prey is seized in the bird's powerful claws, of which the fourth toe is reversible, while the whole are covered with spicules, a nice adaptation enabling the bird securely to grip its slippery quarry.

The osprey confines itself almost exclusively to a diet of fish, and its speed and strength of wing admirably fit it for its life. A notable advantage that it has, compared with some of the birds of prey, and not a few sea-birds, is its ability instantly to rise from the water into which it has plunged. Many ocean-going birds fail in this respect, having to flap their way for considerable distances along the water before they can climb the air. And some of the greatest raptorial birds are as handicapped on land, being unable to rise on the wing out of even a very large hollow. This feature does not apply to the whole group to which we must now pass—the hawk tribe—but only to special examples.

We have in this tribe a very numerous assemblage of birds, grouped into five subfamilies to constitute the family Falconidæ. It embraces some of the most famous of



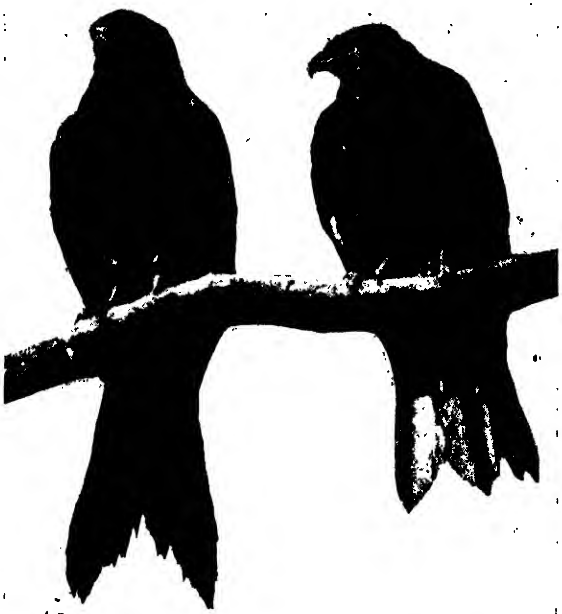
THE CHAMPION OF SUSTAINED FLIGHT—THE WHITE-WINGED ALBATROSS

A SPORT OF MANY AGES AND MANY LANDS

FALCONRY, AS PRACTISED BY LORD AND LADY, IN THE DAYS OF "MERRIE ENGLAND"

FALCONRY AS PRACTISED TODAY ON THE PLAINS OF MANCHURIA

all our birds: the falcons, hawks, kites, buzzards, and eagles. It is not for nothing that long observation has led men to adopt the names of a variety of these fearsome creatures as symbolising acuteness of vision and swiftness of flight; that the eagle is chosen as a national emblem in both the Old World and the New. It is probable that the members of this order possess collectively the finest sight of any group of birds in the world, and correlated with this gift, powers of flight such as are excelled by possibly no other bird—flight which embraces pace, altitude, persistence, and that incomparable downward swoop from the central blue which makes swift-darting bird or fleet-footed quadruped their victim.



THE RED KITE THE BLACK KITE

At what height birds of prey *can* fly we do not know, for no systematic attempt has been made to collect data. One observer, taking a look at the sun through a telescope, saw birds pass at what must have been a height of several miles, and these birds are said to have been kites in quest of prey. It is safe to assume that the falconidæ fly higher than any other birds; their mode of life demands it, for they must strike from *above*.

RED-SHOULDERED HAWK AND YOUNG

There is a saying that "hawks do not peck out hawks' eyes," but the saker falcon will. Trained in Palestine, chiefly for the pursuit of gazelles, it is also flown at kites; and the following description from an eye-witness of a contest of the latter description is illuminating: "The saker, after going a considerable distance from its quarry (a kite), and thereby acquiring what he wanted—superior height—resumed the chase, returning downwards like a thunderbolt on the kite. Blow after blow was struck, and the helpless kite, with his merciless enemy, descended, clutched fast together, their wings expanded, in wheeling circles to the earth, where the kite, already half dead, was soon despatched." All kites, we are told, seem to recognise the saker as their enemy, as, immediately one of the latter is unhooded, all the kites in the vicinity will disperse, though they do not take the least notice of other falcons.

We have no sakers in Great Britain, of course, but we still possess other notable members of the tribe, the golden eagle, the white-tailed eagle, the buzzard, the common or red kite, the kestrel or windhover, the sparrow-hawk, merlin, hobby, peregrine falcon (a name referring to the peregrinating habits of the young birds), the hen harrier, the marsh harrier, and Montague's harrier. To this generous list must be appended the usual qualifying statement that they are among our fast-disappearing indigenous birds; the collector and the enemy of all carnivorous birds are doing their fell work here as elsewhere in bird-dom.

The splendid peregrine comes to us only as a migrant, and while here levies toll upon birds, game-birds among them. But it is admitted that the assailant takes only the weakest birds, and weeds out the unfit

and those least desirable as parents. The stock of game in this country would be far healthier were more members of the falcon tribe permitted to flourish. Hawking is no longer a royal sport, so these feathered hunters are "vermin"! The hobby, merlin, and kestrel all take numbers of field rodents, and even among certain shooting-men "Carefully preserve these birds" is the friendly admonition. But of what avail is the saying of the few wise against the double-barrelled execution of the ignorant and wanton many? Falconry is out of fashion; it is no longer a popular pastime to train birds to kill other birds in this country; in these days falcons have no sporting value, and the economics and æsthetics of the matter do not count.

THE GOSHAWK

The honey-buzzard, so described from its habits of eating the grubs of wasps and bees, will eat rats and mice; but though we ought to welcome it, the bird is among the rarest of our visitors, because it cannot re-establish the foothold that it has lost. The kites, of which the European, or red, was once among the commonest of our birds, even in the heart of London, whither the friendly Thames led them, are now among the rarest of the rare, except in the north and west of the country. Someone pleads for the rat because he is a scavenger We know at what a cost to human life he scavenges! The kite, however, is a scavenger of a different type, and, for all his poetic beauty of flight, prefers to batten, vulture-like, upon dead animals and garbage. In that he is not quite peculiar, for all our birds of prey have the scavenging instinct more or less developed—as has the noble lion!

THE BUZZARD

THE ICELAND FALCON

The majestic eagle will take carrion for choice. Perhaps that is hardly correct as concerns the sea-eagle, which really is a fisherman first and a land forager afterwards. It takes its fish as the osprey takes his, and in the capture displays the blind greed of the vulture, which gorges itself into helplessness. One such instance led to the capture of a sea-eagle which had grappled a mighty salmon that it could not drag from the water, but kept its talons buried in the flesh of its too ponderous victim until a superior power and brain captured both.

But the sea-eagle, fresh from the briny and the breeze, will stoop to the carcase of a dead animal, and, it must be added, it will occasionally take weakling lamb or kid. But that is the rare meal; fish constitute the chief portion of the sea-eagle's diet, and only a fanatic would begrudge it the little food that it takes from the grasp of man. A sight of the bird makes the price seem cheap, for sea-eagles are among the noblest-looking of all birds; and among the eight species we find the largest of all eagles—Stellar's sea-eagle, a bird of 41 inches length, and with a vast spread of wing. The white-headed—wrongly called bald—eagle, the national emblem of the United States of America, is a sea-eagle, and only three inches less in length than the giant of the family.

There are far too many genera of the

THE BATELEUR EAGLE

falcon tribe for specific notice, but we must glance for a moment at the golden eagle, the king of birds as it is named. In this genus, as in the majority of raptorial birds, the female is the larger. An average adult female measures 36 inches or so, but some American examples matching the size of Stellar's sea-eagle have been noted. But not size alone gives this bird its regal title; its superb appearance and majestic flight are chiefly responsible for this distinction. No other bird so suggests power and mastery of height and distance. Cradled upon a dizzy, barren crag, the young golden eagle trains itself to flight by carrying up into the air the carcase of rabbit or hare, dropping this, and recovering it long before it can touch ground. It preys upon hares, rabbits, lambs, fawns, and game-birds, but will swoop like a vulture to a feast of carrion, and, tempted by this noisome diet, fall as stupidly as a domestic duck into the most patent of traps.

THE MONKEY EAGLE

Not many of us will ever have the chance of testing the bird's powers of perception in this direction, for, except in the remote deer forests of Scotland, the wilder hills and desolate islands, this splendid bird is practically extinct so far as the British Isles are concerned. Its boldness would ensure its extirpation if it existed in any numbers, for the fact that it has been known suddenly to stoop from the clouds and snatch a wounded grouse from the man who had shot it, and to seize a hare running before hounds, may be taken as evidence of this bird's small fear of man. We are frequently hearing, too, of children being carried off by the golden eagle, but "not proven" must be the verdict.

Purveyors of these stories know, very likely, that the golden eagle causes the death of deer and sheep, and assume, no doubt, that these animals are carried by the birds to their eyries. But it was the fabulous roc which did that sort of thing, not the commonplace of reality. Eagles may attack young people guarding flocks, but they cannot carry them off, simply because there is a limit even to the lifting power of a golden eagle. When a large animal is killed, the eagle must dine on the spot; bodily removal of the victim is out of the question.

The story of how the eagle accomplishes these considerable "kills" is remarkable, and attested upon unimpeachable testimony. The bird will swoop down upon a deer, and by violent beatings of its wings endeavour to frighten it away from its companions. The victim may assist its assailant by springing to its death down a precipice, or sink exhausted and helpless with terror under the talons and rending beak of the assailant.

Sir Charles Mordaunt saw a young stag driven out from a herd of deer and killed by an eagle by this method in the forest of Glen Feshie, Inverness-shire; but Baron Schroeder was witness of the defeat of another eagle, which, having seized a red deer calf, was splendidly beaten off by the hind, which attacked the bird so courageously with her forefeet as to send eagle, calf, and herself rolling down the steep side of a corrie, when the bird made good its escape, after a rare drubbing.

Experiences differ in regard to the degree of affection for their young displayed by eagles. Some of the birds submit, apparently with complete indifference, to the robbing of their nests;

THE HARPY EAGLE

others resist with such fierceness as to endanger the life of the assailant. The charge of callousness preferred against these birds cannot be admitted to have invariable application. Eagle may differ from eagle as pet bird differs from pet bird, varying between dull and chilly affections, and, at the opposite extreme, the highest example of solicitude and intelligence. As against the cold-blooded disregard for the loss of offspring take the incident cited in Mr. Grimble's "Deer Stalking and Deer Forests of Scotland."

THE CHILIAN SEA-EAGLE

A magnificent adult golden eagle was found caught in a fox-trap, only just dead, for the body was quite warm and lissom when discovered. "He had been caught by the centre claw only, and it seemed wonderful that so powerful a bird had not been able to free himself in his struggles. Clearly he had died of exhaustion, and not of starvation, for within reach of him, and partly eaten, were two grouse and a blue hare, quite freshly killed, with their blood still uncongealed. These could only have been brought to him by other eagles."

Savage and intractable as he may seem to us, the golden eagle is domesticated in Asia. Instead of flying a falcon at his quarry, as was the habit of our forefathers, the Kirghiz huntsman employs the king of birds. The eagle is trained to ride upon his owner's heavily protected wrist, which is supported on a wooden rest fixed upon the front of the hunter's saddle. While his companions beat the surrounding steppes for game, the man who carries the bird rides to the top of some hillock whence he commands a wide view. The quarry may be fox or wolf, the latter for choice if the bird has successfully emerged from his novitiate, during which he has been flown successively at feathered prey and small animals. Brehm describes the hunting of the fox by a domesticated golden eagle. As soon as the beaters have started a fox, he says, the huntsman unhoods and unchains his bird and lets it fly.

THE CROWNED HAWK-EAGLE

THE WHITE-HEADED SEA-EAGLE

"The eagle spreads its wings, begins to circle, and rises in a spiral higher and higher, spies the hard-pressed fox, flies after him, descends obliquely upon him with half-closed wings, and strikes his outspread talons into its victim's body. The fox turns round in a fury, and attempts to seize his foe with his sharp teeth; if he succeeds, the eagle is lost. But almost all these birds of prey, which are as strong as they are bold, have an instinctive feeling of such danger, and the skill to avoid it. The very moment the fox turns, the eagle lets go its hold, and an instant later its talons are fixed in its quarry's face. Triumphant acclamations from its much-loved master, who now draws near, encourage the bird to hold fast,

and a few minutes later the fox, felled by the hunter, lies dying on the ground."

Though the attack on the wolf is made in precisely the same manner, the eagle's bearing is, Brehm notes, from the very beginning, perceptibly more cautious; the size of the wolf teaches it that it has to do with a much more dangerous foe. But it learns to vanquish even the wolf. The picture, though cruel and sanguinary, is interesting as another example of men effecting the domestication of unlikely children of Nature. But the golden eagle is king of birds only when wild and free as Tennyson saw him when:

He grasps the crag with crooked hands;
Close to the sun in lonely lands,
Ringed by the azure world he stands.
The wrinkled sea beneath him crawls:
He watches from his mountain walls,
And like a thunderbolt he falls.

We must pass from this group of birds to another, less picturesque, but not less remarkable—the vultures. Between the vultures and the hawk family, the lammergeier, finest of all the vultures, forms a connecting link. This bird, splendid though it be in appearance, is a vulture in its habit of living almost exclusively upon carrion, but it is more eagle-like than any other vulture, in the fact that it has the head covered with feathers, whereas the vultures proper have the head bare, or at best clad only with a light down. The lammergeier is a mountain-haunting bird, but will drop like a stone to feast upon offal or bones thrown out from human habitations. One species is known to carry a tortoise to a height, and drop it upon a rock to split the reptile's shell. This bird has been identified with the ossifrage of the Bible. Its power of flight may be inferred from the fact that, seeking the plains as well as the hillsides for food, it makes its nest five thousand feet and more up in the mountains.

All the vultures are immensely powerful on the wing, fly with grace and ease at immense heights, and are creatures of beauty—at a distance. At close quarters they are the most repulsive-looking things in animate creation, bare-necked and bare-headed, of murky, hideous plumage, and indescribably filthy feeders. Yet for ages they have served a highly useful purpose, as the chief of scavengers in hot countries. What will become of the myriad vultures of India when our Dependency realises the importance of sanitation and hygiene it is difficult to guess.


THE SECRETARY VULTURE

Vultures, when they fly, soar to immense heights. But if they are to be of service to man, they must come to earth to collect the carrion and garbage which constitute their food. From such tremendous heights do these birds descend to take a meal that observers have disputed as to whether sense of smell or power of vision gives the clue. Dr. Jerdon, describing how the black or cinerous vultures, floating like mere specks in the sky, swoop down and seize flesh thrown down in the open, says it is out of the question that smell can have anything to do with this, for it is a fact that vultures will discover and descend on a stuffed carcase of an animal, while they neglect one well hidden, although it may be putrid and offensive. "I do not mean to assert," he remarks, "that their sense of sight is illimitable, and I do not mean to imply that the very distant birds, that looked like specks, were those to discover the piece of fresh meat, but ever and anon a bird at a lower elevation, but still very high above the earth, would sail past, keenly urged by hunger, would descend lower, and, being certified themselves as to what lay on the ground, would drop in a series of oblique plunges till they reached the ground also. That vultures have also a strong sense of smell is, however, undeniable; many experiments are recorded to show this; and I myself have frequently seen them flying

closely and apparently in an excited manner over a copse or thicket in which a putrefying carcase was placed."

The black, like the griffon, vulture is to be found in Mediterranean countries, as well as in Africa and Asia. Able to undergo long spells of fasting, the griffon is a notorious glutton, and when, following long abstention, it descends from the skies, where it is a most striking and impressive figure, to feed upon offal or carrion, the contrast is most striking. The air-king that was becomes an insatiable, gorging horror, feeding until no longer able to stand, and then lying upon its side to continue its horrid banquet. A vulture still more common in India is the white-backed Bengal species, generally distributed in spite of the localisation implied by its name. Mr. Frank Finn has painted a grim picture of this bird in quest of a meal. He saw it, with other birds of its tribe, assembled in such numbers at an establishment where dead horses and cattle are disposed of at Dhappa, near Calcutta, that, when disturbed and attempting to rise, they beat each other down with their wings, so that many fell into the water. The carcases of the animals were being boiled down, but the vultures did not hurry to secure the flesh thrown to them; they preferred to await the arrival of the garbage-carts. When, for the sake of affording his guest an experience, the man in charge placed before them a skinned, unboiled carcase of a horse, they were suspicious, and at first held off, fearing a trap. Mr. Finn and his friends had to withdraw a little way to encourage the birds to feed. "Then the horse disappeared under a crowd of birds; there was a sound of rugging and riving, and in a marvellously short time it was a clean - picked skeleton." The vultures of India do not confine their attentions to the dead bodies of animals; the ghastliest sight in the land is that afforded by these birds perched with vast, flapping wings, the very emblems of horror, upon the dead bodies of human beings floating silently down the Ganges.


THE FLEDGLING CONDOR

It would seem that there are degrees of repulsiveness even in the taste of vultures. As the eared vultures, of which the Pondicherry is the most notable, seem more brutally grotesque than other vultures, so the scavenger, or Egyptian, vultures are addicted to more detestable feeding habits than their kind. The indescribable abominations rejected by other vultures are the accepted luxuries of this genus. Yet in parts of India this bird is sacred, while its counterfeit presentment figures upon many of the sculptures of ancient Egypt. We must note in passing one vulture-ally of interest in the secretary bird, which has been not inaptly described as resembling in appearance a crane with an eagle's beak. This bird is treasured in South Africa as an inveterate enemy of snakes, but feared as a reputed snapper-up of young birds, hares, and antelopes. Like the vulture and their kin, the secretary bird once on the wing is an aeronaut of the first magnitude.


THE FULLY-GROWN KING-CONDOR

SPOTTED EAGLE-OWL

MILKY EAGLE-OWL

URAL OWL

VIRGINIAN EAGLE-OWL

To most people the splendid condor of the New World is a vulture; to the naturalist, however, he is not a vulture, nor so nearly related to the vulture as are the falcons and secretary bird. The external resemblance is unmistakable, but high authority attributes that resemblance merely to parallelism in development. Peculiar to the New World, the condors include one of the most garish-coloured birds in the king-condor, which is, as regards flesh-hues, a rival of the many-coloured mandril, with orange and purple and crimson marking the naked flesh of head and neck and frontal pouch. This is a forest-haunting bird, but the typical example of the genus, the condor of the Andes, has its home in the mountains.

Although there is but one species, there appear to be two races of these latter birds, one race keeping to heights varying between 9000 and 16,000 feet, the other confining itself to lower levels. The habits of all are the same so far as quest of food is concerned—carrion, sick and dying guanacos, and defenceless lambs and young goats being the staple diet. That these birds, mightiest in size of all the raptores—48 inches in length and of huge bulk—will menace human beings who invade their haunts is undoubted; that they do *not* carry off children, despite American stories to the contrary, is proved by the weakness of their claws.

So far we have had before us in this chapter only those birds whose flight is remarkable for power and endurance, but when we reach the owls we find, as to nearly the whole two hundred species, flight of a different kind. The day birds of prey have powerful long-distance sight to guide them to their quarry; the owls, except the hawk-owls, which do not shun the light, seek their food when the sun is sinking or has disappeared. Their prey consists of living animals and birds, and to be seen these must be closely approached, hence the owl's

TAWNY OWL

BURROWING OWL

BOOBOOK OWL

flight is noiseless. It is a startling experience to have a large tawny owl flying close over one's head in the quiet eventide, and not to hear a sound from its splendid wings; it is still more startling when darkness has come, or what to human senses is darkness, to see one of these birds moving silently through the air, its huge eyes reflecting such light as is really available, and looking like fantastic little glow-lamps.

The silence of its flight is the owl's chief asset in its nocturnal hunting, and this quality is the result of a remarkable modification of plumage, which is soft and downy and noiseless in contact with the air as so much gossamer. Thus protected from betrayal of its presence, the owls of which the British Isles are the happy possessors flit like feathered ghosts over meadow and field, along silent hedgerows, searching farmyard, barn, or granary, ready to drop like a silent bolt upon rat, mole, mouse, or shrew, upon nocturnal insect, even upon an incautious surface-haunting fish.

In this country we have as residents six species of owls—the barn, the fern, the long-eared, the short-eared, the tawny, and the white—and occasionally others visit us. Through these being birds of the night, we know less of their habits than of others whose practices may be studied while the sun is in the sky, but, inasmuch as the indigestible parts of the animals that the owl consumes are disgorged in the form of pellets, we are able to diagnose his diet, and, inasmuch as nine-tenths of the food of the barn-owl, for example, is found to consist of mice, we have a pretty good guide to the bird's value to the country-side. But how many of these inestimable "feathered cats" have perished to adorn a gamekeeper's chamber of horrors?

Owls enjoy a practically world-wide distribution. It is less surprising, then, that they should have become so varied as to form a vast number of species than that one of these species, our barn owl, is common almost universally, and that the short-eared owl, found wherever the former flourishes, crops up even in latitudes of which the barn owl steers clear. Obviously the hardier, more generalised of these birds must be great travellers, or they would not have maintained foothold on lands such as Great Britain, when they have so long been senselessly persecuted. We must have had frequent replenishing of stock, the owl, not being a regular migrant, constituting an exception to the rule as to extirpated local races not being replaced by others. Tiger succeeds to tiger in established lairs and beats in India; rat to rat in England. And possibly the case may be the same in regard to owls. One thing is certain: that where food supplies occur, then owls will be found; and we have noted in a previous chapter how, during a plague of mice in the Forest of Dean, owls of a species never previously

THE SOMALI OSTRICH

THE SOUTH AFRICAN OSTRICH

seen there appeared to share the booty. Owls vary in size, from the 28 inches of the savage eagle-owl (of Europe and Asia and America) to the 8½ inches of the pigmy owl (Europe and Asia). Their habits vary, too, of course; for while the eagle-owls prey upon young fawns, hares, and game-birds, caught quite commonly in the full light of day, we have in the European little owl a bird which can seize nothing larger than a sparrow, and, further, in the fish-owls (confined to Africa, Palestine, India, Malay, and China), birds whose diet is almost exclusively one of fish. Here again occurs a notable adaptation to a special form of life, for the fish-owls have the under side of the claws furnished with sharp spicules, with which the better to grip their slippery victims. In nesting habits, the owls frequent old buildings, holes in trees, or the heavy, dark branches of the latter; some share the holes of burrowing mammals, others tunnel subterranean dwellings of their own. In passing from this order it may be mentioned, for the benefit of the unwary, that the term "eared owls" does not imply that some owls have ears and some have not.

The description applies only to crests or tufts above the eyes, which are not ears at all, but feathers growing in the vicinity of the ears.

Glancing briefly at the flightless birds, we find them, excluding penguins for the moment, in Africa, in the ostriches; in South America, in the rheas; and in Australasia, in the cassowaries, the emeus, and the curious kiwis. It is easy to account for the flightlessness of the cassowary and emeu, for these birds belong to a region practically free, before the arrival of man, from rapacious animals. But the ostrich has discarded all but a vestige of wings, in a land teeming with great carnivores; and the rhea, kin to the ostrich, has the flesh-eating animals of South America to face. The ostrich, monarch of all our birds, in so far as height and bulk are concerned, has developed enormous speed and power of leg. Like the horse, he has sacrificed some of his toes, only two remaining to him now; and feet and legs, the only means of flight, are also his weapons of offence and defence. The ostrich has a future in a state of domesticity. Unless his feathers lose their vogue, his career is assured, for the ostrich is now diligently farmed, not alone in his native Africa, but in Australia and California, to which he has been taken.

The rhea, which is the ostrich of America, is instantly recognisable from its possessing three, instead of two, toes; by the feathered neck, and by the greatly inferior size. Like the ostrich, the male rhea assists in the incubation of the eggs laid by his several mates, gallantly taking the night-watch when danger is most to be apprehended. Cassowaries, notable for the helmet-crowned head, are divided into nine species, scattered throughout Australasia, and have lost even more wing than the ostriches. The emeu, which has much the same habitat as the cassowary, is the largest of all birds, next to the ostrich, which it most nearly resembles in outline as well as in habits, for, like the ostrich, it frequents wide, open plains, whereas the cassowary keeps more to wooded land.

A GROUP OF RHEAS IN STELLINGEN PARK, NEAR HAMBURG

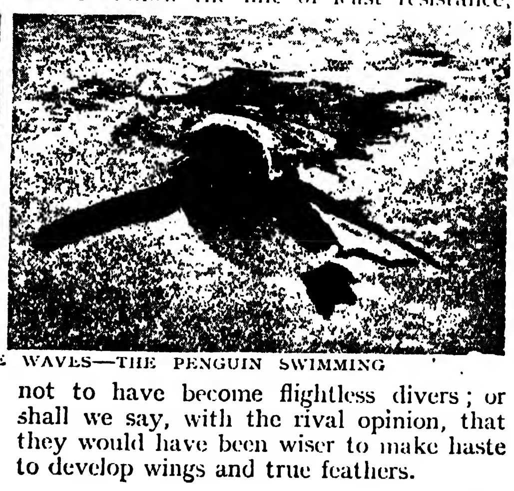
The kiwis, peculiar to New Zealand, have hair-like plumage, approximating to that of the cassowary, but in bodily size they are small; they have four toes to each foot, and a remarkably long beak, with the nostrils placed at the tip. Only vestigial wing-bones remain; and not a suggestion in the external appearance of the living kiwi lingers to tell of the descent of this

interesting bird from progenitors that flew long before the giant moa doffed its wings, and converted itself into a stalking giant. The female kiwi, measuring 27 inches in length, which is some four inches larger than the male, lays a relatively prodigious egg – five inches in length by three inches in width, recalling that of the extinct æpyornis, which had a circumference, measured lengthwise, of 36 inches and a girth of 30 inches.

A COLONY OF PENGUINS ACCLIMATISED IN A EUROPEAN PARK

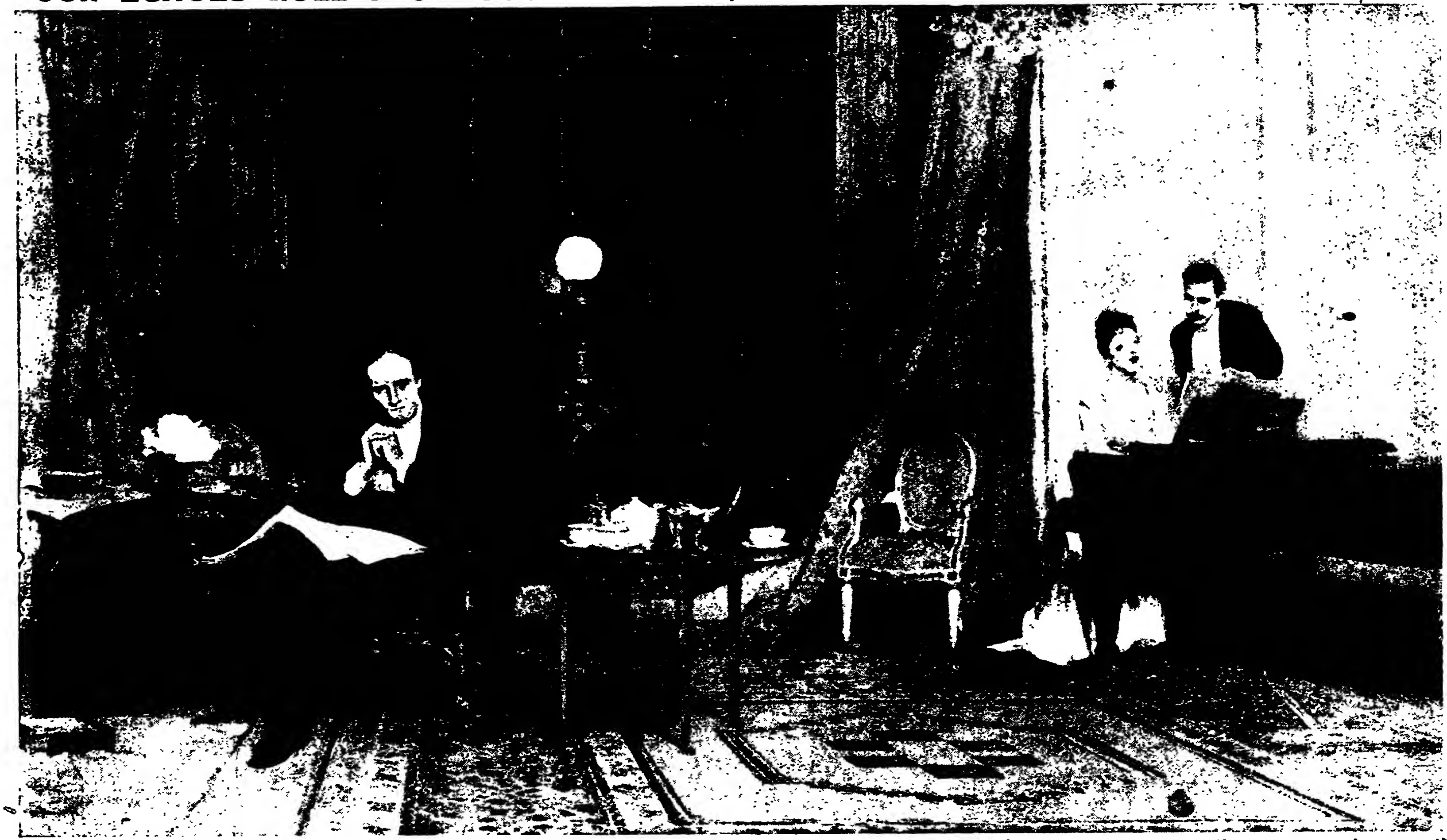
There are birds in whose habits of today we trace clear evidence of degenerate flight, such as the kakapo, or owl-parrot, of New Zealand, which, from long immunity from attack by carnivores, has so neglected the use of its wings as to become little better than a parachutist, planing down from trees, which it ascends by climbing, and using its wings, when running along the ground, as the ostriches use theirs, as sails or balances. We must close our chapter, however, with a reference to the penguins, nearly a score of species of them, all south of the Equator, ranging from South America to the dreariest wilds of Antarctica, with never a flight-feather among them. Degenerate or primitive—and the former, of course, is the more generally accepted term—the wings are true paddles, by means of which the penguin in the water, with its diving and leaping and plunging, presents so dolphin-like an appearance as to deceive even a trained observer.

The emperor penguin lays but a single egg, and this is incubated during six weeks of unbroken winter nights by both birds in turn, without nest or shelter. The egg is balanced between the feet and body of the parent bird, and the chick, when hatched, has at first to be similarly protected, for a touch of the ice would be fatal. But with the best of care the mortality among young penguins is extraordinarily high, 75 per cent. of dead, having been counted after the hatching season. Even under less rigorous conditions as to weather, the young birds are constantly menaced by rapacious skuas, and by death from starvation, owing to their wandering from their parents. The penguins have done well so long to maintain their place in life, but they would have done better not to follow the line of least resistance, not to have become flightless divers; or shall we say, with the rival opinion, that they would have been wiser to make haste to develop wings and true feathers.



A BIRD THAT TRAVELS UNDER THE WAVES—THE PENGUIN SWIMMING

"OUR ECHOES ROLL FROM SOUL TO SOUL, AND GROW FOR EVER AND FOR EVER"



THE MOST REAL OF WORLDS WITHIN THE PHYSICAL SENSES, AS ILLUSTRATED BY SIR W. Q. ORCHARDSON'S PATHETIC PICTURE "HER MOTHER'S VOICE"

THE SENSES AND THE SOUL

The Extension of the Effects of Physical Stimulation into the Region of Psychology

THE NEED FOR THE USE OF THE WORD SOUL

HITHERTO, in our study of the mind, all has been plain sailing, for though we encounter mysteries and difficulties there can be no doubt as to our course. The beginning of our psychical life lies in sensation, in the power to feel. Having seen that, plainly we required to study the senses as fully as possible, and in large measure the structure of the body helped us, for many of the senses have special sense-organs, such as the eye and ear, which we could study *seriatim*.

So long as we can hold on to bodily tangible things in this way, we feel sure of our going. But here we must break away, and though our study is to be no less real than heretofore, it must be much less concrete, for the simple reason that, while the eye is a thing to see and handle, a desire, a regret, a premonition are impalpables, "imponderabilia," or unweighable things, in the old phrase; and the mind does not follow such things so easily, though they are part of itself, as it follows external physical things. The intellect was evolved for dealing with the outside world, as Spencer taught us many years ago, and there alone is it really at home, as Bergson has shown us today.

Still, our task is easier than in the past, for though we have to go mainly among bodiless things, we have certain signposts and headlands, occasionally visible, to help us. At least we can study the bodily happenings which coincide with evolution, the brain structure which corresponds to speech, and so forth. We do not take leave of the body altogether; and, indeed, our progress in the realm of psychology, for many years past, has chiefly depended upon the help derived from physiology, even in those higher realms which we are about to explore.

Having named, defined, and numbered our sensations as far as possible, we have to see what becomes of them, what consequences they produce. Sensations are only the beginning. They lead to the rest of the mind, and indeed they matter only because they do so, only because they affect behaviour or conduct, in the widest sense of those words. A sensation that had no such consequences would be nothing, and indeed such a sensation is unthinkable, for it would be a cause without effects, a loose end in the sequence and structure of the universe. The consequence of the sensation may be obvious and immediate, as when we are struck and strike; or it may be obvious and delayed, as when we retaliate after twenty years; or it may never be obvious, as when we remember and hate, but pretend to forgive; it may never show itself in external conduct, sooner or later, but it is operative none the less in the conduct of the mind. We may not know it; we may utterly forget the blow or the insult or the kiss, as we suppose, but in the right combination of circumstances, or near death, evidence will appear that it is not forgotten, but has made us different, even in the deepest behaviour of the mind, though consciousness knew it not.

In some ways perhaps, this to which we thus come is the most important and characteristic principle of the new psychology; nor is it necessarily the worse because it so largely agrees with what the teachers of morality and students of conduct from that aspect have taught throughout the ages. Prophets, teachers, poets have again and again insisted, in all times and places, that all experience matters, that we are different for everything that happens to us. But ordinary language, often inexact in all spheres, is so particularly, flagrantly, persistently inexact in the sphere

of the mind, that we very rarely realise the great psychological truth upon which modern students insist. We hear a name, and forget it the next moment or the next day, and say it has "slipped clean out of my mind"; and though sometimes when we hear it we recognise it, showing that something somewhere remembered, often we cannot even recall the fact that we had ever heard it. Each instance we observe, in ourselves or our friends, of the retention somewhere of words, habits, sensations, which appeared to be lost, to be non-existent, astonishes us, and naturally so, for it is contrary to everyday experience.

The Unobliterated Record Kept by the Mind, though Sometimes Hidden

But the study of the subject shows that we should be astonished no longer. Everyday experience is wrong, as when it positively witnesses the sun moving across the sky. The fact is that nothing "goes in at one ear and out at the other." The brain is between them, and what it has it holds. If the words be properly defined and understood, it is true that we forget nothing.

Obviously this does not mean that we can recall every sensation we have ever experienced. In fact, myriads of sensations have occurred in us, and have affected us, which *we*, our conscious selves, have never experienced; they happened too deep beneath the surface of consciousness for us to notice. We can hardly expect to replace in consciousness what never had a place there. Nor does it mean that, though we cannot recall a sensation—say, the sound of a name—we can at least recognise it when it is recalled for us. Often, as we have seen and well know, we cannot; we are astonished at things we see written in our own hand; it is incredible that we can ever have written them; we could swear that we did not—but we did. Plainly, then, the assertion that we forget nothing requires full and proper definition before it can be accepted.

The Constant State of Change of the Recording Soul

"To live is to change," as Cardinal Newman said long ago, and as Professor Bergson, in his "philosophy of change," insists today. Inanimate things exist and persist, but time, as such, does nothing to them. We say that time does, but we mean that, in the course of what we call time, they are affected, by wind and weather and the worm, or what not. Time in itself does not exist for them; it is only something we invent to measure events by. But "real time," as Bergson calls it, exists in and for the living creature alone, for to live *is* to change, and all the changes of its past are summed up and have their effect at any moment of the life of a living creature. It *is* the sum-consequence of all its past. Time, therefore, is real for it. This is the deepest meaning of memory—a deeper and wider one than is convenient for the ordinary use of the word. This is the meaning which has led certain thinkers, like our own Samuel Butler, author of "Erewhon," and the Continental biologist Hering, to look upon heredity as, at bottom, the expression of the memory of living creatures—memory which means consequence not only in the particular individual, but also in its offspring, so that we are not merely the sum of our own past, but the sum of the whole past of life. All that fascinating department of speculation is beyond our present purview, but it helps us to realise what modern psychologists mean when they speak of Memory in its wide sense, and with what interest they study all experience, all sensations, as destined in some degree to determine the constitution and behaviour and destiny of the individual for ever afterwards.

Evil Experiences Irrevocable but Not Necessarily Fatal

This, then, is the tremendous fact which we have to face when we study the results, the future fruit of our sensations, both our conscious and our sub-conscious sensations, both those of external things, and those of our own doings. But it must not be misunderstood in the fashion, only too familiar to students of human thought, which breeds hopelessness, despair, a feeling of impotence in the clutches of the past. That is a perversion of the truth, and of the doctrine here laid down as the deepest teaching of modern psychology. If we have to allude to religion in dealing with it, that is because religion deals with the conduct of man, and therefore cannot be left out of any true or useful discussion of psychology. And, at once, what we have been saying must have reminded the reader of familiar teaching associated with religion. For there are schools of religious thought which have always perceived the lasting importance of all experience, which is what we here assert, but have thence reached conclusions to which we must demur. It is not here asserted that all evil experience is not only irrevocable, but, in itself, fatal. It is not here admitted that what we call sin, including forbidden experiences of the senses, is

something which, being permanent in its consequences, is necessarily disastrous in its consequences. Psychology teaches, sternly and benignly, that all experience has consequences; but it can make no distinction between what morality calls good or evil experience in this respect, and it cannot possibly say that what was, at any time, evil or good remains so unchanged, somewhere in the individual record.

The Denial by Psychology of the "Guilty Stain" of Theology

That is the idea which is expressed in the Recording Angel, and all those forms of religious teaching which conceive of a man's acts and experiences as being permanent in the sense that they are permanently, separately, indelibly, *unchangeably* recorded, somewhere. It is the idea of a "stain upon the soul," which nothing can efface; the idea which has led immense numbers of men and women to commit suicide in religious melancholia, because they saw no hope of freedom from the "guilty stain."

Now, all this is precisely and utterly what modern psychology denies. The resemblance between the truth and this awful and ghastly perversion of it is obvious enough, but it should deceive no one who will reflect for a moment. Modern psychology asserts that to live is to change unceasingly, and that to live is itself an act of Mind, which underlies all vital processes. Mind is a living thing the only living thing—and the mind of man accordingly changes, in "real time," as a consequence of all that it does, feels, perceives, thinks, suffers. Thus everything matters. Every deed reacts upon the doer; every experience—of a landscape, or of having had a large meal—tells in its due degree upon the personality, the self, the Ego, as upon the body. The living man is pushed forward, so to say, by the whole of his past, which is ever being added to, and is ever changing him.

The Ever-changing Flux of the Everlasting Mind

But while this doctrine agrees with the teachings of the past in asserting the importance of *all* experience—for we really forget nothing—it evidently denies and utterly contradicts the idea of a man as a kind of permanent statue, upon which there can exist an irremovable stain. *That* idea is of a kind of living being that is a contradiction in terms, for it is evidently not alive, but dead, like a statue. The living mind cannot be permanently "stained," for it is alive, it is in flux, ever-changing, like a stream of the ocean, taking in all manner of experiences, absorbing them into itself, changed and different in consequence; but immeasurably the opposite of what some theologies have conceived—a fixed, changeless, dead *thing*, on the outside of which, or in a book about which, certain facts of behaviour are recorded. The behaviour, the good or bad thought, the harmless or evil pleasure, the deed, the desire, the emotion, the work, the play—these are not something to do with a man, something about him, something to add up in a column under his name, something important because irrevocable and recorded in indelible ink in a book, or even tattooed upon his skin; these *are* the man; these have entered into the living substance, the Mind, the Self of him. He at any moment *is* the sum and issue and fruit and expression in the present of all his play and work and thoughts, true and false, and feelings and intentions and sorrow and joy.

Everything matters, then; we agree with those theologians; but it matters in an immeasurably deeper and more infinite and momentous sense than they imagined.

How We Ourselves are the Lasting Record of Our Past

Each of us is his own recording angel, and the book in which he writes. But the book is not a diary, with a leaf for a day, in which the "written word remains." The book is alive, it is a fluid book, in which all the writing is no sooner recorded than its identity is gone, for at once the letters flow into all that have preceded them, and the result is a writing which corresponds to no page of the past, and yet comprises the issue and consequence of them all; and that writing is you *now*, but not you when you have finished this chapter or paragraph, for then already your attention, understanding, misunderstanding, assent, dissent, liking or dislike, will have changed you. But because you are you, with your past, your experience, your memories known and unknown to yourself, your identity, your personality, the you-ness of you remains; and though you change unceasingly, though you can never return and be again what you were yesterday, and though you must continue to change, here or hereafter, if you are to be a living Mind at all, yet all the while you will be yourself, and not another, because the whole of your unique past remains, stored up, but not stored up, unrecognisable, but consequent, in You.

These are conceptions of the self, of the real nature of man, which have only to

be stated to be accepted; and if they involve the relegation of much familiar teaching on great matters to the limbo of puerile folly, the sooner that end is achieved the better, for then we shall be nearer a development, renascence, purification of religion, which shall be more valuable for man in proportion as it understands him better.

And now we are ready to study the consequences of our sensations, for we have an enhanced idea of their importance, and we have firm hold of a truth which is the beginning of wisdom, and which physiology alone ignores or denies. For we have already seen that a sensation is liable to be a stimulus, and that a stimulus commonly produces a response, a corresponding action which we call reflex; and physiology and psychology have to concern themselves largely with such reflex actions. But their insistence upon the response is apt to lead us to think that no more now remains to say of the sensation, the stimulus to which the reflex action was the reply. That is an error of the most serious kind, turning us aside from any true understanding of personal development, or of the deep meaning of memory.

The Latent and Reserved Responses that May Come From Early Impressions

No doubt the body and the mind reply to the blow, the caress, the tune, the odour, in some way or another, though indeed there may be no immediate reply; but the memory of the stimulus, and of the response or of the failure to respond, or of the effort by which response was checked—these remain, and have their lasting consequences. Furthermore, a reflex need not be immediate. Physiologists reckon what they call the "latent period" of a reflex, during which nothing appears to happen, though it is true that the response is being prepared.

It lasts, in a given case, for perhaps three-hundredths of a second, they say; but it may last a lifetime, and on his dying bed a man may respond to sensory experiences which he learnt at his mother's knee, or in very different places. Properly understood, the period of latency matters not; reply is reply, whether by return of post or after "the night brings counsel," or whether you do not "get back" on your enemy for a generation, when at last you have the chance to ruin his son. The truth remains, and is illustrated alike in every case, that we forget nothing; that everything of which we have sensation affects ourselves always, not by some plastered substance adhering without, but by internal change and development, somewhat after the fashion of a kaleidoscope, though no material image can do justice to the case of the mind's life.

Let us, then, here leave on one side the questions of response, action, external reply to sensations, on the ground that they must be studied later, when we know more about the Self. Will, desire, purpose, resolution, consistent striving—all these facts of the mind, showing themselves in muscular acts of a thousand kinds, must not be considered yet, the assertions of nineteenth century materialism notwithstanding, for the sufficient reason that we must first try to learn more about *that*, thing or person, material or spiritual, which or who wills, intends, or strives.

The Something in Us that No Materialism Can Ever Explain

Many a man, it has been said, has "too much ego in his cosmos," but it will not do to leave out the ego altogether. Our first business now is therefore to try to follow our sensations, of all these kinds we have studied, and see what happens to them "inside," and whose sensations, if anybody's, they are.

Materialism says they are nobody's sensations. When we speak of the self, or the soul, it replies that there is no such thing. It is content to say that when the eye is punched the fist projects, and that, in reality, is just the same as the case of a pugilist's ball which, when struck, returns; the response is mechanical, obeys mechanical laws, and there is no more need to attribute an ego to the pugilist than to his punching-ball.

The fact was that physiology was so interested in tracing the external response as to forget all the rest. In point of fact, if you strike a punching-ball, it may return and hit you, once, and immediately, and that is all; but if you strike the pugilist, you may find that he strikes more than once, or not at all, that he bears resentment or contempt, that he remembers, perhaps when you thought he had forgotten. Something is there which you cannot see, and which the punching-ball has not.

The Wonderful Multiplicity of Our Simultaneous Sensations

Each one may be his own subject and object of observation here. Observing ourselves at any given moment, we realise that we are the subject—note that irresistible form of words—of a variety of sensations.

Any moment of waking life will serve for an illustration, and we are all familiar with instances which serve to show the multiplicity of simultaneous sensations. At a meal, in the theatre, in church, in the country or the town, we are being assailed, so to say, by sensations of many contrasted kinds. You watch the play or the opera, and you simultaneously see and hear; the chocolate-peppermint you suck is giving you sensations of taste and smell, your hand clasps precious fingers, and your other side is proportionately uncomfortable owing to the contact of a stranger. Your constrained position gives you various kinæsthetic sensations from muscles and joints, and you are frightfully thirsty.

Specimen Sensory Sensations While Listening to a Play

This is the first illustration that happened to come into the writer's head, but the reader's condition at this instant will serve quite well enough. Here is a brief technical description of the facts: " At any moment of waking life the state of one's consciousness, in so far as it is sensational—and every state of consciousness is largely sensational—is due to a multitude of stimuli playing upon the sense-organs within and on the surface of the body, and exciting, indirectly through the sensory nerves, a number of different specific psycho-physical processes in the sensori-motor arcs of the various sensory areas of the cerebral cortex. Each of these excites an elementary quality of sensation of greater or less intensity, and all these are fused with various degrees of intimacy to form the complex sensory background of consciousness in which, by successive efforts of attention, we can discriminate different qualities."

Psychical States that Visit Us at the Play and Are Not Sensory

Observe that the state of consciousness is not wholly sensational. As you listen to the play, and are yourself played upon by the various sensations described—and by many more, for you hate your neighbour's loud breathing, and someone is talking behind you, and there is a blessed (or disagreeable) draught, and your boots are tight, and you feel as if you wanted to blow your nose, and so on—you are also the subject of many other psychical states which are not sensory.

You like or dislike the play, you wish you were somewhere else, you are astonished at the contrast between the play and what you had heard about it, you are annoyed because the actor you came to see is not playing, you are wondering why you never came to see such a fine play before, you want to destroy half the audience for laughing in the wrong places, you hope your companion is enjoying it, you mean to come again at the first opportunity, and so on literally *ad infinitum.*

But even if we try to simplify the problem by leaving out of account all these deeper and subtler psychical components of it, we have to face this amazing variety, contrast, opposition of mere sensations at any given moment, and ask ourselves how and where and in what or whom they manage to exist simultaneously? We are undeniably conscious, through and by them all, of ourselves. We have a unity; we are not a mere heap of " sensori-motor arcs," or assemblage of psycho-physical processes. I am here, and I feel such and such, all at once. But we have seen that the brain consists of a number of separate centres and arcs, that one of these may be thrown out of action and the rest remain intact, that their working, say, of eye and ear, is independent; where is the seat of this unity of consciousness, this first-hand unchallengeable feeling of the Self, the single subject of all these sensations?

No Area of the Brain Where the Sensations Are Pooled

Time was, and that not long ago, when the physiologists were sure that, somewhere in the brain, there must be a place or centre, a *sensorium commune,* or common resort, of all sensation, where every separate item of our sensations was somehow registered, and so fused with all the others as to account for this unity of consciousness. Various parts of the brain, the function of which was not known, have been labelled accordingly, in the hope of finding a material place which should explain (and explain away) the Ego. But the increase of physiological knowledge has steadily dogged the steps of these interpreters. Wherever they settled, and said, " Here is the centre where all sensations are pooled, giving us the illusion of unity we call the Self," inquiry has shown that the area in question had a definite function of its own, equilibration, touch, taste, or what not; and, in fact, there now remains *no part of the brain whatever* on which this theory can find rest for the sole of its foot. The evidence of neurology, and of the exact study of the individual senses, and the law of Müller, which shows how each sensory centre is specific, yielding only its own kind of sensation, however it be stimulated—all these have disposed of the

theory of "physiological fusion of sensations," either in a *sensorium commune* or in any other way. And the soul returns.

The fusion of all these sensations having been proved to be not physiological, for the brain keeps them all apart, and there is nowhere where they can be pooled, it is impossible to deny that it must be psychical. Here are the words, not without some historical interest, written by Dr. McDougall, in 1905, at the very beginning of that advance of science beyond nineteenth century materialism, which is now triumphing on every hand, above all through the influence of M. Bergson.

The Recovery by Science of the Idea of the Soul

"We are compelled to admit, or so it seems to the writer as to many others, that the so-called psychical elements are not independent entities, but are partial affections of a single substance or being; and since, as we have seen, this is not any part of the brain, is not a material substance, but differs from all material substance in that, while it is unitary, it is yet present, or can act or be acted upon at many points in space simultaneously (namely, the various parts of the brain in which psycho-physical processes are at any moment occurring), we must regard it as an immaterial substance or being. And this being, thus necessarily postulated as the ground of the unity of individual consciousness, we may call the *soul* of the individual."

After the strange aberrations of the recent past, the study of the senses has thus brought science back to its senses. *You* do exist, after all. Indeed, it is not *mal à propos* to remember that, after all, the best that logic could go, in the nineteenth century, for the definition of matter was in terms of mind, for John Stuart Mill defined matter as a "permanent possibility of sensation," which is to refer the existence of all the outer world to That which feels.

The Need for Believing Not Only in the Mind's Sensations but in the Mind Itself

Verily we may say that the soul returns; and the refutation of materialism by physical science, which, as was lately shown in the First Section of this work, has divested matter of its materiality, is complemented by the advance of psychological science, which has worked right through the brain, without encountering the soul, only to find the soul more necessary than ever. The reader will do the argument the justice to observe that we here use the word soul as the equivalent for the Greek *psyche*, and that the argument is not to be credited or discredited, understood or misunderstood, with reference to any theological uses of the word.

Let us now hark back, two or three centuries, to a former discussion of the great question before us. That discussion culminated, for the time, in the famous "Essay on the Human Understanding," which was written by Dr. John Locke, whom we commonly regard as the father of modern psychology. In that great book, Locke set himself to study the doctrine of "innate ideas," according to which such ideas and beliefs as those of God and immortality are innate in all of us, and are not derived from without us, or in any way received through the channels of sensation. Locke came to the conclusion which our study of sensation will have led us to accept, almost wholly, that "Nothing is in the mind that was not first in the senses." In contravention of the theologians and scholastic philosophers of his time and before it, Locke declared that all our ideas, without exception, are derived from sensation and reflection on past sensations; in other words, all our ideas are derived from individual experience, and the senses *are* the "gateways of knowledge."

Nothing in the Mind but its Sensations—Except Itself

But what we have just been studying will make us a little uncomfortable in the presence of Locke's dictum, as it stands, for it almost reads as if sensations *were* the mind, which would practically mean that *the* Mind was a myth. Hence we are ready to receive with gratitude the famous brief addition which Leibnitz made to Locke's words, thus: "Nothing is in the mind that was not first in the senses, *except the mind itself*." On every ground that addition is necessary. In the preceding pages we have seen one—that the unity of consciousness, in the presences of multifarious and simultaneous sensations, requires us to believe in a Something, "the mind itself," *of* which those sensations are the sensations. A totally different field of inquiry leads to the same conclusion. Locke's argument, as it stood, led to the conclusion that the mind is nothing, in the sense that a sheet of blank paper is nothing.

Sensations are everything, nothing is in the mind that was not first in them, he said: and thus all that what we call the mind amounts to is a "tabula rasa," a shaven tablet, upon which sensations inscribe what they will. But the modern study of

heredity, and of the natural differences between individuals, has shown us all what is indeed so evident on a moment's observation—that the mind is something more than a blank or vacuum to be filled, and is a real, distinct, unique something in each of us, which has characteristics, powers, tendencies earlier than all experience. Experience, indeed, is *its* experience; *it* was there first. True, in a sense, is the assertion that nothing is in the mind that was not first in the senses, but truer still is the addendum, *except the mind itself*.

The soul returns; and its return is the leading fact of the history of psychology during the last generation or so of human thought. The senses go to furnish, or contribute to furnish, its very stuff; they give entry to its nourishment and its building material, but the "City of Mansoul," of which they are the gates, is more than any or all of them put together. Yet let us not suppose that this is simply the swing of the pendulum back from one extreme to the other, and that modern psychology humbly begs pardon, and yields place to the teachings of the past upon the soul, all and sundry.

The Deficiency in Language for the Expression of Modern Ideas of the Mind

It is just the risk of this misunderstanding that has deprived modern writers of half their necessary vocabulary. If we use the word soul nowadays, a whole host of theological ideas which are not in the mind of the writer and only confuse his argument, arise in the mind of the reader.

Hence, very often, there seems to be no choice but to use the Greek word *psyche*, in italics, as if the English vocabulary were not rich enough. "Mind" does not suffice, for it is so often used to mean only the intellect; and if we do use the word soul, we are promptly misunderstood by the so-called rationalists and by theologians alike—the first claiming that we have abandoned science, and the second that we have practically recited the Athanasian Creed. It is necessary to protest, and to insist that the word soul shall be used as it was by Dr. McDougall in the passage we have cited, in a meaning which is strictly rational, and yet not inimical to religion.

But whether all the champions of reason and religion respectively will let us use the word in a sense which honours both is another question. A similar difficulty is obvious enough in the use of the word "spiritual," which would be extremely useful in the study of philosophy and of man, but which is practically debarred from use by its associations with cant and chicanery, with spirit-rapping and table-turning, and which has thus been abused more than any words in language, except in the case of "Christian Science" itself.

The Changeful, Fluctuating Life of the Soul

Even such a term as the "Ego" has its disadvantages, though we cannot do without it. Rightly, no doubt, the philosopher begins with it, and can indeed assure us of its real existence without reference to those modern researches into the functions of the brain which we have lately reviewed. Long ago Descartes laid down the doctrine, "Cogito, ergo sum"—I think, therefore I am. It is impossible to begin except with the "I," and therefore it is impossible to reach any other conclusion other than that it exists.

But we are not to delude ourselves into fancying that our problems are now all solved—that there is no further need to prosecute a science of psychology. No, indeed; the soul is alive, and all the problems of the living soul, and of every living soul, remain. It changes from moment to moment, since to live is to change; it is infinitely sensitive, learns everything, or may, and forgets nothing; it has its ups and downs, its states of happiness and distress, hope and fear; its parts war with one another, struggle and survive, or are repressed, and there is no discharge in that war; as for its ultimate destiny and such supreme questions, we have much hard, plain inquiry on lower planes to deal with first; but at least we shall proceed to investigate the emotions, the instincts, the intelligence, the memory, the will, with hope of success, having first satisfied ourselves that there is a psychical something, which is the subject—or the ruler—of all these states.

The Failure to Pitchfork the Soul out of Human Nature

And though this assurance may seem scarcely worth stating to some, they will only be those who have never examined it. The rest of us, who have been through the inevitable stages of inquiry and discovery, and renewed inquiry, and who know what the teaching of science seemed to indicate only thirty years ago, in the dawn of physiological psychology, will prize aright the assurance of today, that however often science, falsely so-called, may seek and seem to pitchfork the Soul out of Human Nature, the substance of which *is* Soul, it will surely return.

A STATUE OF THE BOY BACCHUS IN THE GRÆCO-ROMAN DEPARTMENT OF THE BRITISH MUSEUM

ALCOHOL AND THE BRAIN

Is Alcohol Really Helpful to the Brain, or Does It Only Seem to be Helpful?

TREATMENT OF THE DRINK CRAVING

When we have said our say here about the bodily organs, in any connection, we require to go back to first principles, and remember that the body exists for the brain, and the brain and the body for the mind. The action of alcohol upon the liver or the blood, or the resistance of the lungs, is doubtless important for the hygiene of the body, but the hygiene of the mind is paramount, after all; and the problem of treating the alcoholic, or threatening-to-be alcoholic person, must be studied no less from the psychical than from the physical side.

We have already seen that alcohol has a special affinity for nervous tissues, like its chemical relative ether, and like certain other members of the two series which these typical anæsthetics represent. But directly we try to describe the action of any drug upon the nervous system we find ourselves required to understand how that system works—of which no man yet knows more than the outlines. Yet those outlines can serve us here. Thus we can readily distinguish between the central action of alcohol upon the nerve-centres of the brain especially, and its local or peripheral action, as it is called, upon certain nerves, especially of the limbs. Further, we can pass the border—that mysterious border, which means such infinite things—between physiology and psychology, and can study the action of alcohol, not in terms of the brain at all, but in terms of psychical behaviour. Each of these three divisions of our subject has its own importance.

Ordinarily, alcohol has no observable action upon the peripheral nerves—those outside the nervous system. But in certain cases when alcohol has been taken, usually in large quantities, for some time persistently, these nerves are very peculiarly affected. Why they should be thus singled out we do not know; nor do we understand the important fact that different people vary widely in respect of the particular organs, or series of organs, which are liable to be attacked by alcohol. One person will exhibit injury in the liver only, another injury in the nerves only, another injury in conduct only, and another will take more alcohol than any of these, and show no sign of injury at all. These personal differences have been far too little appreciated by doctors or the public, but their importance is of the first order. However, a very large proportion of those who show evident injury from alcohol show it in the peripheral nerves, and very notably in the motor nerves. Above all, those of the limbs, and especially the lower limbs, are affected. We cannot say why, any more than we can say why lead, in like circumstances, prefers to attack certain muscles of the arms.

The inflammation of the nerves thus induced is known as alcoholic neuritis; and as the motor nerves of the lower limbs are specially attacked, the patient's powers of walking or using the legs, even for standing, are seriously impaired. The calves of the legs are usually very tender on pressure, and the patient is very much to be pitied. Certain mental symptoms, only recently recognised, are commonly associated with this peripheral neuritis—the sum total of the damage to the patient's *psyche* being known, after its closest student, as Korsakoff's psychosis. But the local damage to the nerves is its chief feature, and it need not here concern us further, except to say that removal of the cause is customarily followed by very complete recovery.

The damage appears to be inflicted upon the nerves, or the very nerve-ends in the muscles, perhaps, by the alcohol as it circulates through them and soaks through into the tissues from the blood-vessels. But such damage, though it may be so complete

as to cause absolute paralysis in the part affected, is easily recovered from if the nerve-cells in the spinal cord, whence the peripheral nerves proceed, are themselves intact. New nervous tissue can be formed in old nerve-sheaths, for the vital centre, the nucleus of the nerve-cell, which governs nutrition, can always achieve regeneration if its own powers be unimpaired. Here, therefore, in medical language, the diagnosis is usually easy, the treatment is obvious, and the prognosis is usually favourable—assuming, of course, that the treatment is applied.

And we observe that, though the local damage may be so extreme, the prognosis is favourable, because, after all, the symptoms are only due to local poisoning and destruction, not of the nuclei or nerve-cells, but merely of the fibres which run from nerve-cells, and which can readily be replaced. There is reason to suppose, however, that the psychical accompaniments of peripheral neuritis may leave more permanent traces.

The Action of Alcohol on the Central Nervous System

We pass now to the central nervous system, brain and spinal cord, and inquire into the action of alcohol there. At once we find plenty to study, quite apart from cases of alcoholism or evident alcoholic poisoning, of which peripheral neuritis is so conspicuous a type. For a single dose of alcohol, far smaller than would be required to cause death, or even anything that could be called drunkenness, will have a very real action upon the brain and spinal cord, though none upon the motor-nerves of the limbs. The study of any neurotic drug requires delicate apparatus if it is to be prosecuted with any nicety, and the observer requires much experience. The pioneer in this field was the great German student of insanity, Professor Kraepelin, of Munich, who gave many years to its study, which he approached from the position of a firm believer in the virtues of alcohol. In his psychological laboratory, Professor Kraepelin contrived or adopted a number of devices for making exact experiments upon nervous and mental processes; and he especially directed himself to the task of getting some accurate external records of its action, apart from the feelings and experiences of the person experimented upon.

This is a point of the first importance, and modern psychology is profoundly indebted to those who have realised it. Of course, we want to know, at every moment and in all imaginable circumstances, how the person whom we are studying feels, what he thinks, what he is conscious of, how his Ego is affected. All that we call subjective, and we can only learn it from the subject himself. Assuming him to be honest, intelligent enough to observe his feelings, and record and describe them, that is well, though the difficulties are large, especially since the very act of consciously observing one's conscious state involves the production of a new state.

The Difficulty of Making Observations on Oneself, and Being Watcher and Watched

But now we see that all this time we want an objective examination of the individual, our subject. He must tell us what he, the subject, experienced; we must observe what he, the object of our observation, did. Then we must put the subjective results and the objective results together, and compare them.

In the particular case under discussion the results of this comparison are among the most notable paradoxes of science. It is generally believed that a man is stimulated by alcohol, and thus thinks, acts, responds, more quickly, more brilliantly, more effectively, under its influence. This may possibly be true in certain cases, especially where the individual, when he takes the alcohol, is under the terminal, depressant influence of a previous dose. We also know that analogous drugs, such as opium, may liberate the imagination, for Coleridge wrote his "Kubla Khan" under its influence, showing how a narcotic drug, attacking first the centres of control, may simulate the action of a stimulant. But Professor Kraepelin proved, now many years ago, that the action of the normal brain is hampered by alcohol.

The Drinker's Deceptive Opinion that Drink is Helpful to Him

The owner of the brain is of a very different opinion. Tested with a column of figures to add, with a simple matter of logic, a test of memory, the formation of a simple association of ideas, or with tests of quickness of response, and quickness in distinguishing different stimuli and responding accordingly, the normal subject under the influence of alcohol thinks that he is doing splendidly. On the contrary, he is doing very badly indeed. Though he seems to himself to be working at great speed, with facility and accuracy, the cold clock or tuning-fork, marking its hundredths of a second, finds that he is working more

slowly than normally, and when his results are examined they are found to be less accurate. The consciousness of effort, of fatigue, of concentrated attention, is dulled by the drug, so that the subjective and objective verdicts upon its action are contradictory.

A recent instance of the point in question may be quoted, as one of very numerous observations which have since confirmed the pioneer work of Kraepelin.

"The want of efficiency produced by alcohol is well shown by a series of experiments arranged in Sweden, with the object of ascertaining the influence of alcohol upon efficiency in marksmanship. None of the men experimented upon were abstainers. Three corporals and three privates were chosen for the purpose. In the first series of experiments no alcohol was given. In the next it was provided, and in the third it was again withdrawn. Spirits and beer were alternately tried. The results of these experiments indicated, without a single exception, a reduction of the accuracy of aim as a result of the alcohol consumed. Yet all the men, after receiving their allotted portion of alcoholic drink, had declared that they felt far more capable—but found themselves deceived."

The Uniform Scientific Results in Favour of the Non-Drinker

Here, as in the action of alcohol upon the blood, the temperature, the resistance to disease, and in several other details, we find a singular justification, by modern science, of the Biblical description of alcohol as a "mocker." The thing is essentially a fraud—it seems to make us warmer as it cools us, and cleverer as it befools us. These observations upon marksmanship have been extended to such matters as the manipulation and firing of big guns on battleships and elsewhere; and it is the uniform result of all these comparative inquiries that led the German Emperor to his recent pronouncement that the sea wars of the future would be won by the most sober navy.

A word of warning may be added for any readers who may care to experiment along these lines. Useful work can be done by examining many people, under various conditions, abstainers and non-abstainers, but no less useful observations can also be made upon single individuals, if they go the right way about it. The experience of many years and countries has shown that errors are very apt to creep into these tests, and the results are worthless unless they be avoided. For instance, whether the subject be an abstainer or non-abstainer, whether he wishes the result to come out in one direction or the other, or is quite indifferent: it has been found that he is morally certain to be influenced—sometimes in one way and sometimes in another—by the knowledge that, in a particular test, he has or has not taken alcohol.

The Impossibility of Testing Alcohol on Oneself with Fairness

So important is the sheer reaction of the idea in the subject's head that in the most recent and exacting tests, mainly made upon themselves by some English psychologists, notably Dr. McDougall, great care was taken to provide two sets of drinks, so contrived that the subject could not tell, by the taste or the colour or in any other way, whether or not the alcohol was being taken. To contrive such drinks was by no means so easy as it may sound, but certainly the results were far more accurate and valuable for the taking of this precaution. Further, the most elaborate care must be taken to check results and guard against all disturbing elements, such as variations in the diet, exercise, sleep, and so forth. Also, the effects of the alcohol require to be studied separately for large doses, small doses, frequency of dosage, dosage with meals, between meals, and so forth. It is only the alcoholic mind that can suppose such a problem as this to be soluble by the verdicts of casual conduct. But, though much further work would be welcome, the results long ago obtained by Professor Kraepelin have now been found to apply in a host of other directions under a host of novel conditions with remarkable uniformity.

Does Alcohol Have a Stimulating Effect During a Dinner-Party?

Now it is a notorious fact that, notwithstanding all that has been said, an apparently stimulating effect of alcohol upon the brain is constantly observed at every dinner-party. When the company assemble and make each other's acquaintance, they are comparatively silent and reserved, not to say dull, but when the champagne begins to circulate they reveal to each other hitherto unsuspected powers of conversation and humour; while after dinner, in the smoking-room, the men find it as easy to talk as it is difficult to get a hearing. Has not the alcohol in such a case plainly stimulated the intellectual and lingual powers?

Here is another paradox. Let us recall

what the students of the nervous system tell us as to the superposition and hegemony of its parts, so that, as the late Dr. Hughlings Jackson taught us all, the nervous system may be conceived as consisting of a number of *levels*, each of which exercises a power of control or inhibition upon the levels beneath it. The lowest level, which is also the oldest in the history of the race, is the most stable; whereas the highest is the most delicate and unstable, being also the latest of evolution in the history of life. But, in the terse dictum of the neurologists, "Last to come, first to go." A paralytic or narcotic agent, the onset of sleep, of senility, of death, attacks each level successively, from above downwards. The function of the highest and latest level of all is pre-eminently that of inhibition or control, judgment and self-restraint.

When you enter the reception-room before dinner and encounter a number of strangers you are on your best behaviour; you are not going to make a fool of yourself or "give yourself away" before people of whom you cannot be sure. Whatever stores of intelligence and humour you may have are by no means left at home, but the highest level of your brain is doing its work, and you have yourself well in hand.

How Character Relaxes Under Alcohol, with an Effect Socially Pleasing

Then comes the champagne, and the first part of your nervous system which it paralyses is the highest and least stable. Its action is arrested; caution and restraint, and possibly even common prudence, especially in the novice, are cast to the winds, and you let yourself go. You "give yourself away," and your real self becomes apparent, your hidden thoughts and tendencies, as never otherwise. This the ancients expressed in their brief way—"*in vino veritas*," in wine the truth.

To interpret this as the stimulation of thought and speech is pure ignorance—very excusable until the neurological discoveries of the nineteenth century, but hardly creditable now. And if the nature of the action be doubted, let but the drug be "pushed," as doctors say, and speech, formerly fluent, will become incoherent; thereafter even the older centres will be attacked, until in extreme cases the "vital point," the centre for respiration in the lowest part of the brain, is paralysed, and the patient dies of acute alcoholic asphyxia.

But do not let us suppose that the symptoms, in the familiar early stages, are necessarily deplorable. Individual idiosyncrasy plays a very large part here, as race does also. Everyone who has organised a dinner for the raising of money knows at what stage the subscription list should be passed round, and why; and there are opportune moments, as easily predictable, at which to approach creditors, borrowers, prospective fathers-in-law, and the like. Many people only unbend and become interesting, courteous, or even tolerable companions when alcohol has begun to weaken their inhibitory level, and their "temperament" gets a chance to express itself. On the other hand, some of us are quite pleasant even when we are sober.

The Dangers that Follow from the Moral Unbending Caused by Alcohol

These differences are noteworthy, because the recognition of them makes us less censorious and more useful. If we happen to feel fairly happy, fluent, capable, sure of ourselves without special aid, we have no right to blame those who naturally have recourse to alcohol in order to reach a state which we can attain more safely and permanently. The temptation is wholly different for them, and any pharisaical attitude on our part is worse than ugly. But it behoves us also to remember that the substance which, when we ply our friend therewith, makes him so much more companionable and therefore conveniences us, involves grave danger for him.

The writer was recently at Abbotsford, the home of Sir Walter Scott, where, together with a company of tourists from many parts of the world, he was shown the large tumbler used by Robert Burns for "just a wee drap before breakfast," as our guide happily explained. The joke was well rewarded with what Solomon once compared to the "crackling of thorns under a pot," but one of the company remembered how that tumbler killed the poet, ended in disgrace a rare young life, and robbed mankind of an unimaginable legacy of song. These are not the jokes to laugh at until poets are common; and no one will laugh at them then.

The Want of Proof that Genius Has Ever Been Stimulated by Drugs

But if poetry is indeed so valuable, and if alcohol throws the reins upon the back of Pegasus, it may fairly be argued that there is a real place for it in the economy of human life. Intelligently used, it should be available to enable us to get at the stores of humour, genius, insight, poetry, music, and so forth which men may possess. The

experience of mankind is, however, contrary to this assumption. Doubtless, if it could be contrived that alcohol should dissolve the lid without any of it leaking through and damaging the contents, the case might be otherwise. But, in fact, the drug affects, in some degree, the levels of thought and imagination, even while, in greater degree, it annuls the customary restraints to their action. The testimony of great men, and of those who have observed them, is clear on this point; and we may be sure that alcohol has drowned far more genius than it has drawn forth.

Helmholtz, the supreme genius of Germany in the physical sciences, testified that, in preparation for really first-rate work, it was necessary to drop alcohol altogether. The case of the wonderful fragment "Kubla Khan" has often been cited, and certainly should be considered, though the drug in that case was opium. No one who reads the life of Coleridge and his poor son Hartley will be prepared to commend alcohol or opium for poets thereafter. But how "Kubla Khan" would have ended had the author not been interrupted by a debt-collector, we cannot say. The poem as it stands, with all its beauty, has just the characters, positive and negative, which tally with our knowledge of its origin.

DR. WILLIAM MCDOUGALL

As everyone knows, and as has been insisted upon by all the recent writers on the psychological relations of alcohol, this drug has a very definite relation to what may be conveniently called the racial instinct. The mythology of Bacchus, and the meaning of "Bacchanalia," may be paralleled from the Old Testament, or from human history and legend anywhere. The action is explained if we remember Shakespeare's phrase about the man who takes alcohol "to steal away his brains."

Shakespeare, who knew something about alcohol, and had brains to steal, was as right here, in the eyes of modern science, as in a host of other and more remarkable instances. Paralysing the "brains," which in this phrase stand for the powers of inhibition and control, and for those of the higher pleasures and desires, alcohol leaves lower areas of the nervous system uncontrolled, and thus unduly free to express themselves. The pure moralist will commonly say that the drug "calls out the baser instincts," but such a phrase misses the true psychological analysis; and the use of the word "base" in connection with the instinct which alone conditions the continuance of the human race is an instance of the deplorable injury which the moralist often inflicts upon morality. But, apart from these criticisms, we must wholly assent to the warning against alcohol for youth or adolescence. As Sir Victor Horsley says, "for the sake of national morality as well as physique, it is clear that in no form whatever should alcohol be used by the young, either in childhood or adolescence."

The opinion of Dr. Clement Dukes, the distinguished physician to Rugby School, has elsewhere been referred to in this connection, but his exact words should be quoted. In his standard treatise, "Health at School," he writes as follows:

"Beer is a drug which deadens the will-power and excites the animal instincts of the young; its relation therefore to immorality is most momentous. . . . In plain English, a master who allows his pupils to drink beer at bedtime, and a parent who sanctions it, implicitly says to them: 'I give you this beer at bedtime, well knowing that it will blunt your intellect, deaden your conscience, and diminish your will-power; and that at the same time it will excite your animal instincts.'"

Undoubtedly progress is to be recorded. A generation ago the medical profession condemned alcohol for children; a few months ago it assembled again at the Mansion House, in London, and condemned it for adolescents; and Dr. George Keith, the famous author of a "Plea for a Simpler Life," and Sir Hermann Weber, both nonagenarians, have condemned it for the elderly. As for the rest of us, some facts and arguments for the reader's consideration have here been adduced, and he will judge

for himself. It is not necessary here to discuss those actions of alcohol upon the mind and brain which show themselves, in severe cases, as delirium tremens, or in alcoholic insanity. The symptoms and management of such conditions are outside our present need, but it is worth while to note how the prospects of recovery, under proper conditions, which begin with abstinence from the cause, are now regarded much more favourably than in the comparatively recent past.

It is probable that much of the havoc wrought in the alcoholic brain is toxic to the cells affected, but not lethal. Many are poisoned and ill, but not dead, though the *post-mortem* appearances and microscopic examination have often led us to look upon many of these cells as actually killed. What this means is that, when and if the victim of alcoholism gives up his drug, he will make a very much more complete recovery than we used to suppose. It is impossible to believe that he will ever be the man he might have been at his age without the alcohol, but his pitiable state of mind and body are more to be looked upon as a chronic intoxication, daily maintained by a daily toxic cause, and less as the result of definitive destruction of living cells than we used to suppose.

The False Claims Made for Drugs that Are Said to Cure Drunkenness

The problem of dealing with the individual drinker, who is evidently injuring himself, remains. That problem is largely complicated with the public, legislative, and national aspects of the alcohol question, which do not concern us here. But though we cannot forget how easy it would be to cure anybody of alcoholism—though not necessarily of the desire to take alcohol—by force, the problem is a very different one so long as the will and *psyche* of the individual concerned have to be reckoned with. The treatment of alcoholism is no problem, medically, for the cause is obvious and the treatment is to remove it. But practically we are being for ever faced with the problem under other conditions, and the victim, or his victims or friends, are called upon to decide what course they shall pursue, what advertisement they shall answer, which of several chances they shall spend precious time and money upon. Here some definite medical knowledge is very much to the purpose, no less in saying what should be avoided than in more positive directions.

It may be dogmatically asserted that no drug which will cure the desire for alcohol exists. The multitude of secret remedies which are offered to the public are all to be condemned. Cures are effected in association with them, but they never cured anybody. The crave is largely psychical as well as physical, and suggestion, hope, fear, faith, sympathy may all be potent in affecting it. The drugs which are used for the purposes of their vendors have been examined and found worthless. They contain nothing that is not familiar to honest and experimental science. But if anything is more certain than any words are needed to say, it is that alcohol does not cure alcoholism; and when the secret remedies used all over the world are examined, alcohol is found to be the essential ingredient of most of them. Many consist of nothing else.

The So-Called "Remedies" for Alcoholism Themselves Largely Alcoholic

The "remedy" is administered in the institution, or sold to the patient and taken at home; and, of course, the unfortunate person is well pleased, for he believes himself to be taking no alcohol, and his need for it appears to have vanished, thanks to his blessed drug! All the while, of course, he is getting into deeper difficulties, as the event reveals. The fact that in some cases, even in this way, a patient may believe himself cured, and by an effort of will aided by faith may *be* cured, proves nothing more than we knew in any case. On the whole, the harm done by the administration of alcohol for alcoholism in this way can scarcely be overstated.

Both in England and America one lamentable discovery has followed another in this respect. The present official inquiry into the composition of patent medicines will lead to wide exposure of the facts, but those relating to the secret use of alcohol for alcoholism must be specially insisted upon. The sale, in strong solutions, of alcohol, with fancy names, for other maladies, may be undesirable, but the sale of alcohol for alcoholism is obviously intolerable.

The Most Recent Analysis of a Much-Praised Remedy

The "British Medical Journal" has quite recently published an analysis of what is by far the most reputable of these remedies, and has shown that it consists of 75·5 per cent. of alcohol, and nothing else of any consequence. It is described as "a combination of vegetable drugs which has been guaranteed to be innocuous," and the patient who takes it is instructed that "it is absolutely necessary in order to

ensure a permanent cure that a full course of 24 days' medicine (24 bottles) shall be taken without a break, so that the alcoholic or drug poison may be thoroughly eliminated from the system, and thus prevent a return of the crave." Alcohol is to be eliminated from the system by a fluid three drops of every four of which consist of alcohol, and which is to be taken "every hour while awake" for twenty-four days. Whoever prepares the mixture must be aware of its composition; and we are left wondering how anyone can sell alcoholic "treatment" that is simply an alcoholic liquor, half as strong again as whisky.

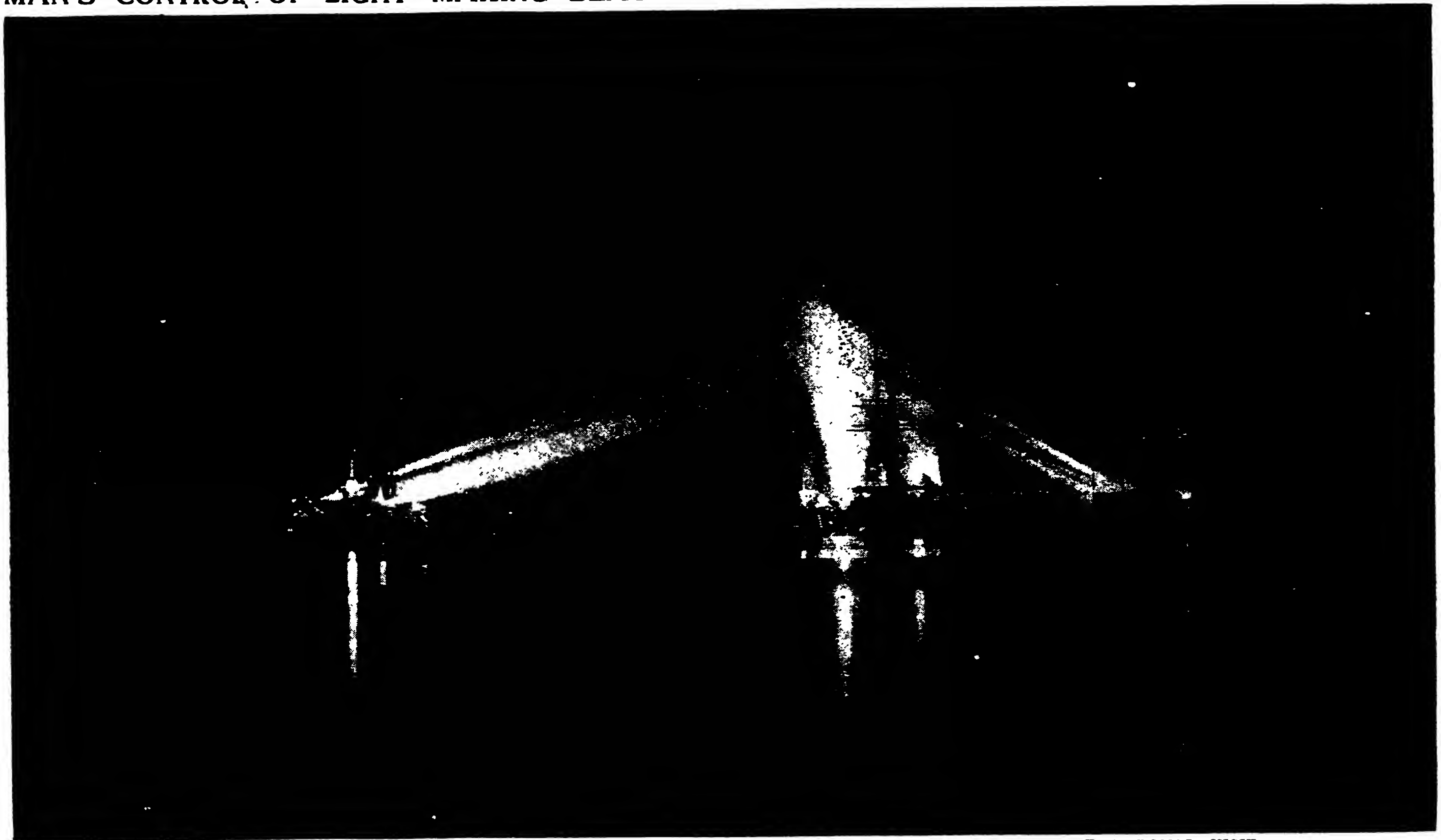
The reader will see that our warning against these secret "cures" for alcoholism is justified. On the positive side, the principles to remember are that this is a double malady, psychical and physical, and requires double means for its cure. In a large proportion of cases there is no cure for the crave, which is inborn, and the forcible exclusion of alcohol is the only alternative. In many others, an apparent cure is followed by a relapse. But it is on record that many cures reckoned hopeless do recover, and hope should not readily be abandoned. Honestly conducted institutions exist where the patients are neither given alcohol nor allowed to bribe the attendants for it. These afford the best chance for ordinary cases, apart from such special agencies as the influence of some person or of religion. In them the physical and psychical aspects of the malady are recognised and dealt with simultaneously. The possibilities of success in any given case cannot be gauged by reference to the figures published by official and other institutions There are cases which are irreformable because the individual was never properly formed in the first place; and since large numbers of such unfortunates go into reformatories they depreciate the statistics of success.

At present the medical profession as a whole may fairly be said to know little of this extremely difficult subject, which is one for the expert, if any department of medicine is. Practically no instruction whatever is given on it in the medical schools, though the treatment of delirium tremens is never omitted. The best omen for the future in this respect is the existence of the Society for the Study of Inebriety, of which the secretary is Dr. T. N. Kelynack, of Harley Street, and which numbers among its president, vice-presidents, and council practically all the greatest names of the medical profession today. Any members of the general public may become associates of this society, which is not a temperance society at all, and undertakes no propaganda, but exists for the gaining and dissemination of knowledge on this subject. Its quarterly publication, the "British Journal of Inebriety," occupies a unique position in the English language, being our only representative of the class of scientific journal that deals with this matter on the Continent; and the steady increase in its membership and associateship is the best promise for a time when the medical profession at large will be nearer the standard of its scientific leaders in this subject.

PROFESSOR KRAEPELIN

More widely effective still is the International Congress on Alcoholism, which met in London in 1909, at The Hague in 1911, and meets at Milan in 1913. The published Reports of these Congresses comprise the most recent and authoritative research on alcohol and alcoholism throughout the world. It is on evidence and research of this order alone that we are entitled to base any conclusions in a work which is avowedly scientific; and the time has certainly come when all who are interested in personal hygiene, for themselves or those near to them, should realise that this subject, while not without its religious and moral aspects of high importance, is also a part of that science which is called physiology, and requires to be studied as such in the modern age The present writer is only concluding the performance of a plain duty if he expresses the opinion that the best quantity of alcohol, for consumption in health and disease, for work or play, is *nil*.

MAN'S CONTROL OF LIGHT—MAKING BEAUTIFUL "THE REALMS OF CHAOS AND OLD NIGHT"



A SEARCHLIGHT DISPLAY FROM BATTLESHIPS AND FORTS AT MALTA ON THE OCCASION OF A ROYAL VISIT

The pictures on these pages are by courtesy of Messrs Edison & Swan, The Keith Light Company, Messrs. Chance Bros., Mr. Ellis, and others.

POWER OVER DARKNESS

The Battle Between Gas and Electricity, and the Marvels of the Mercury Lamp

THE CHEAPENING OF ARTIFICIAL DAYLIGHT

So great a power has man already obtained over the gloom of night that if the electric furnaces working at the Niagara Falls were combined into one white glow, the radiance could be seen from the moon. Possibly the whole electric power obtainable from the vast waterfall might be transformed into a signal fire that would be visible from Mars.

Yet a hundred and fifty years ago the civilised races scarcely had any stronger means of overcoming darkness than those possessed by savage and barbaric peoples. In the days of Shakespeare the lighting of both palace and hovel was exceedingly primitive. The guttering of rushlights, and the splutter and smell of faint lamps fed with animal fats, made a Court festival at night a dim and not altogether pleasant affair. Till about the middle of the eighteenth century we could show little advance upon the methods of lighting invented by some ingenious cave-dweller of the Age of Stone. He used a small, shallow lamp, filled with animal fats, in which was placed a bit of dry wood or a wisp of grass that served as a wick. Even the Romans in the days of their power had a somewhat similar lamp of burnt clay, holding a little fish oil or animal oil. Our forefathers hunted the whale chiefly for lamp oil, and Hull and Whitby flourished for hundreds of years as the centres of the sperm oil industry. The Chinese from time immemorial had kept their picturesque lanterns alight by means of oil crushed from vegetable seed; but it was only towards the middle of the eighteenth century that colza oil, obtained from the wild cabbage, began to be largely used in our country.

The lamps, however, in which the new oil was burnt remained quite primitive in construction until Argand of France discovered a way of supplying air both inside and outside by means of a hollow burner into which a tube-shaped wick was fitted. The increased supply of air to the burning flame brought about a stronger and quicker combustion, with the result that the light became clearer and brighter.

It is impossible to understand the frame of mind and the social condition of both the savage and civilised races of the past unless regard is had to the feeble power over darkness that the whole of the human race then possessed. When this planet of ours turned away from the light of the sun, and swung out into the mystery and darkness of interstellar space, strange and horrible powers seemed to sweep in upon the earth. Anybody who as a child has walked alone along a dark country road on a windy night will remember the primitive superstitions that assailed him. Ghostly forms crouched amid the bushes, uncanny things whispered and moaned and glimmered in the fields, the trees, and the hedgerows. These fears of the night have haunted man, and the ancestors of man, for millions of years. Probably they were based at first upon the terror of nocturnal beasts of prey; but when the early savage discovered a means of guarding himself from bodily enemies by means of a camp-fire, lighted with a fire-drill or sparks from a flint, the awful gloom around him still worked on his mind and imagination, so that he peopled the darkness with spirits of dread and horror.

This extraordinary superstitiousness in regard to the imaginary terrors of the night has been responsible for much of the delay in the evolution of the clear, rational, constructive powers of the human mind. Men were fairly reasonable in broad daylight, but when night fell their primitive fears awoke, and the old superstitions resumed somewhat of their ancient sway over the imagination. It is not very long since the

traditions of the Dark Ages entirely lost their power over the minds of the larger number of civilised people. Even Francis Bacon, the apostle of experimental science, believed in the existence of the evil spirits of darkness, and looked upon them as legitimate objects of study. It is not too much to say that the greater part of the cruel, sanguinary, mind-deadening practices and ideas in primitive and pagan religions were engendered by man's terror of darkness. It was mainly in the walled and partly lighted towns that the human reason threw off its fears of the shadows of night, and became irradiated with steady reason, self-confidence, and scientific curiosity.

Probably there have never been wanting bold criminals who, playing on the general fears, used the darkness to do wrong to their fellow-men. Only by bearing in mind how ill-lighted were the streets of London in the eighteenth century, and how dark and deserted were the towns and villages on the roads at night, can we understand the social conditions under which the footpad and highwayman pursued their nefarious business. The country was then admirably organised; by its military and naval power it dominated the world; yet so small and slight and costly were the means of lighting the public thoroughfares that the footpad was invincible. The criminal part of the population of even large towns was able, when night set in, to defeat all the machinery of the law. Persons still living have been waylaid at Knightsbridge, in London, for even important thoroughfares in the olden days were avenues of gloom. The few dim street-lamps that occurred at intervals were merely put up as guiding signals, enabling the belated wayfarer to find his way from point to point. They served practically the same purpose as the coastwise lights that enable a pilot to steer a ship along the dark seas.

HUMPHRY DAVY EXPERIMENTING AS A BOY

When, acting on an idea of the ingenious Lord Dundonald, Murdoch lighted the Soho Works in Birmingham with coal gas in 1802, the successful experiment did much more than provide a new luxury for the civilised world. It was one of the greatest advances ever made in the means of preventing and discouraging crime. The double chain of brilliant lamps that stretches like a thread of fäery jewels down the road of a great town, illuminating the fronts of the houses, and sending up into the midnight sky a broad, yellow glow that dims the stars, is one of the grand instruments of modern civilisation. Without it, the footpad and the burglar would still prevail against our splendidly organised police-force. Crime would again become easy, and thousands of weakly, mischievous persons, now terrorised into law-abidingness by the difficulty of fighting against the forces of order, would creep out to rob and plunder, and even to slay. Light is cheaper than the police.

In the last few years there have been many complaints about the glare of a large modern city at night. The blinding electric radiance from various shops, the flashing out of huge illuminated advertisements in many coloured lights, and all the myriads of public and private illuminations, certainly produce a glaring effect at times. More than three-quarters of a century ago Tennyson sang of the country boy:

> "Who at night along the dusky highway near and nearer drawn,
> Sees in heaven the lights of London flaring like a dreary dawn."

But this was in the days when a rather dim gaslight was still engaged in driving the colza and sperm oil lamp out of existence. Now the monstrous city, with seven and a half million inhabitants, blazing with electric arcs and metal filament lamps and incandescent gas flames, pours up into the darkness of the outer universe a stupendous volume of radiance that strikes an observer on a country road with something like awe. It is like a vast, incomparable volcano of luminescent energy produced by some tremendous natural force beyond human powers of calculation Enormous, steady, and as punctual in appearance as the dimmed army of stars that sweep the skies above, it displays the might of the human race in a way that scarcely any other work of men can

It is, indeed, hard to match this majestic show of human power with any permanent thing of natural origin on our planet. The Victoria and Niagara Falls are small beside it. Only the tremendous and transient energy of some great volcano, or of some tempestuous sea, can compare with it in sublimity. But volcanic eruptions and tempests do not endure as the shining energy of London does. It is the most wonderful monument of man's power over the primæval darkness of night.

There are other inventions of great importance, such as the railway, the steamship, and the electric telegraph, which have variously had a large effect upon the economic conditions of the world. But the discovery of cheap and abundant sources of powerful artificial light has probably produced a more profound revolution on the habits and activities of men. It has co-operated with the cheap printing-press in clarifying and steadying the general intellect, putting an end to idle terrors and vain superstitions, and thus training the human mind for its high work of establishing the kingdom of man. It has removed one of the chief opportunities of the criminal. It has saved the sailor from shipwreck and the railway traveller from collision. It has turned, for many a worker, the short, brief days of winter, in which his family had to go on short rations, into as prosperous a period of employment as the bright summer months. And it is artificial light of great intensity, used in the microscopic examination of microbes, that has helped to defend mankind against the germs of disease, and illuminate some of the subtlest problems in other branches of science.


THE JAPANESE LANTERNS IN A STREET IN TOKIO

So we must put these and other advantages obtained from an increasing control over the artificial sources of light against the modern follies of the luxurious class that turns night into day, and against the blinding misuse of electric lights in garish shops and illuminated advertising stations. It is quite true that we are now living in an age of glare. Even in many private houses of the fairly well-to-do classes artificial light is abused rather than used. It is possible that more eyes are now weakened by the employment of too strong and dazzling an illumination than by poor and feeble light. But a new class of men—

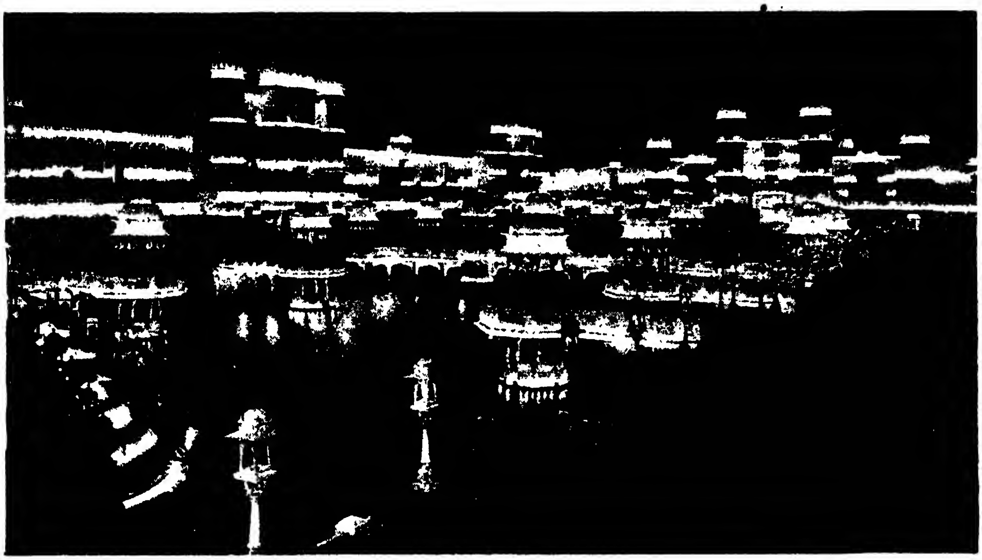
the illuminating engineers—have organised themselves into powerful bodies in the chief countries of the world; and they are beginning to demand that they should be consulted by architects and builders in the construction of every kind of house and building.

They have reduced to a science the relation of light to the human eye, and they are able to arrange every means of artificial lighting in a way that makes all work done in an artificial light more healthful and more comfortable than is now generally the case. What they particularly urge at the present time is that they should be entrusted with the arrangement of lights in our elementary schools, and they protest against the scholars doing home lessons in ill-lighted homes. With home lessons abolished, or all homes well lighted, and the illumination of the schools carried out on scientific ideas, the reformers contend that there would be a marked and permanent improvement in the powers of vision in the younger generation.

The illuminating engineers are also working and agitating for a general improvement in the artificial lighting of factories and workshops. The fact is that a considerable number of various kinds of working people have purchased regular hours of labour throughout the year, and regular wages in winter time as well as in summer time by submitting to the danger of being hurt by machinery in poorly lighted factories. A large number of serious accidents are directly due to bad lighting. In mining also there is room for—indeed, in many cases a crying need for—better artificial light. A now well-known miners' disease has been directly traced to deficient illumination.

So, wonderful as is the new power over darkness that man has recently acquired, much yet remains to be done before the full benefit of all this progress reaches the people generally. In some cases we have not yet learned to make proper use of the incandescent gas lamps and the electric filaments and arc lamps with which the inventors of new means of lighting have supplied us. In other cases, the work of the inventors is not yet completed. Neither gas nor electricity is yet used in an efficient manner for lighting purposes. No means have yet been discovered of transforming energy into light in an economic way. The best of modern lamps—the flaming arc lamp—is but a makeshift. The civilised world is like the Chinese boy in Charles Lamb's fantastic story about roast pig. The boy was the first discoverer of the delights of cooked meat, but his only way of cooking it was to burn down his father's house, so that the pig should be roasted in the flames.

Our ways of producing artificial light are almost as primitive. We take something and make it very hot, though heat is the very thing we do not wish to create.



THE DECORATIVE VALUE OF ELECTRIC LIGHT—A SCENE IN THE FRANCO-BRITISH EXHIBITION OF 1908, WHEN THE CARBON FILAMENT STILL PREDOMINATED

Still, we make it very hot, often using about 99 out of 100 parts of energy in generating wasteful, unwanted, and injurious heat. So we go on until the thing gets white-hot and begins to shine. Then, like the Chinese boy who liked roast pig, we think we have performed wonders.

This process of producing light by heat is known as incandescence. In the latest of electric filament lamps, for instance, an electric current is forced through a metal wire that strongly resists the passage of the electricity. All the energy expended in forcing the current through the wire is transformed into heat, and the wire is made at last so hot that it shines. In an ordinary way the wire would quickly be burnt up, just as the wick of a lamp is. But the combustion is prevented by pumping the air out of the glass globe, so that little or no oxygen remains to combine with the metal of the wire and burn it away. Thus is effected a durability of the various kinds of filaments used in electric glow l mps which, when electric power is greatly cheapened, may bring them into universal use.

It was mainly due to the work of T. A. Edison, in 1878, and J. W. Swan, in 1879, that the incandescent electric lamp was developed into a practical success. Edison first employed a platinum wire, but Swan had the happier idea of using a carbon filament. He treated cotton thread with sulphuric acid, and obtained a parchment-like substance which was fairly durable. The modern carbon filament is made from cotton-wool that is first dissolved in some solvent, and then formed into a long, semi-transparent thread that looks somewhat like catgut.

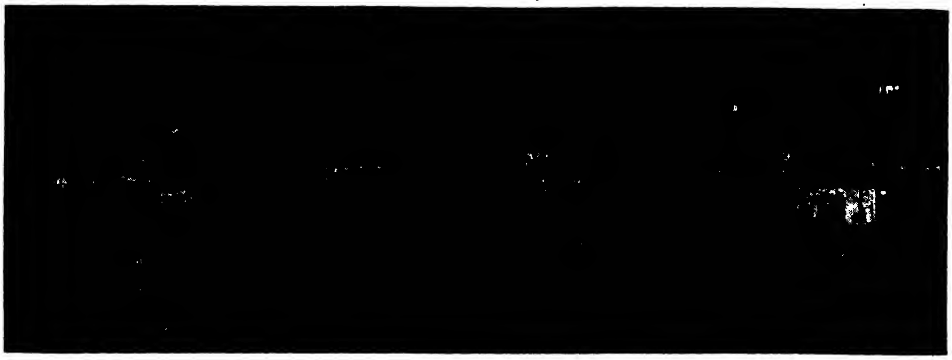
In an attempt to find some substance that would endure heating to a higher temperature than the carbon filament, Edison and Lane Fox began to experiment with various kinds of rare earths, such as thorium and zirconium. But it was found that no mixture of any of these earths and carbon was permanent. So the inventors gave over their researches, and bent their energies to the task of making the carbon filament lamp a handier and brighter and more efficient means of lighting than the gas jet that had become the common light of the civilised world.

THE INDUSTRIAL VALUE OF THE NEW ILLUMINANTS—A FACTORY AT NIGHT AS BRIGHTLY LIGHTED AS BY DAY

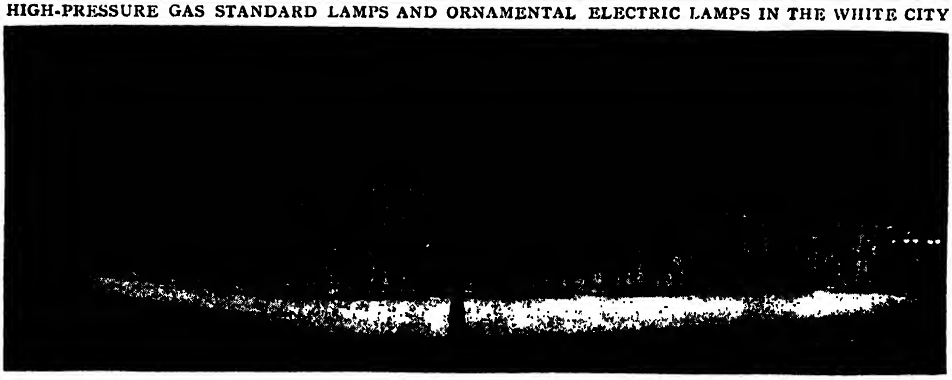
For some years the victory of the electric lamp seemed to be inevitable. Year by year improvements were made in the manufacture of the electric bulbs, and of the means of supplying electric power in a large way to private houses and big buildings; and though the powerful gas companies began by ridiculing the new illuminant, the time soon came when electric lighting seriously threatened to displace gas lighting. The cost of gas in the ordinary batswing burner was nearly ninepence for a thousand candle-hours. The best class of glow lamp, on the other hand, produced its light at an expense of

THE EFFULGENT FLOODING OF WIDE SPACES

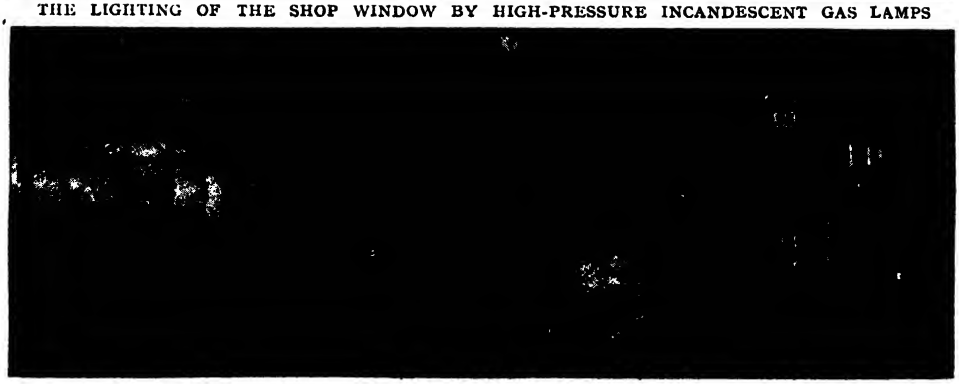
VICTORIA STREET, WESTMINSTER, ON A RAINY NIGHT



HIGH-PRESSURE GAS STANDARD LAMPS AND ORNAMENTAL ELECTRIC LAMPS IN THE WHITE CITY



THE LIGHTING OF THE SHOP WINDOW BY HIGH-PRESSURE INCANDESCENT GAS LAMPS



CANNON STREET, LONDON, WITH A ROW OF GAS LAMPS IN THE DISTANCE SWINGING IN MID-AIR

COUNTERFEITING DAY INDOORS AND OUT

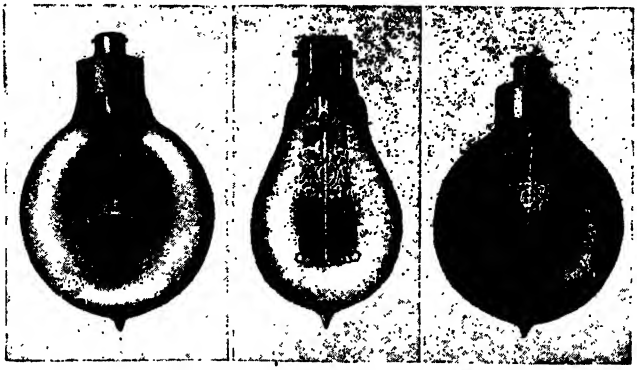
A ROW OF HIGH-PRESSURE GAS LAMPS MAINTAINED BY THE SHOPKEEPERS IN LEWISHAM HIGH ROAD

THE LIGHTING OF A WORKROOM IN A LARGE DRESSMAKING ESTABLISHMENT

under sixpence-halfpenny for a thousand candle-hours. More important still, in the lighting of great buildings and large outdoor spaces, was the progress being made in the electric arc lamps. The closed arc lamp produced its light at last for twopence a thousand candle-hours, while the wonderful flaming arc lamp created the same amount of light at an expense of about a halfpenny.

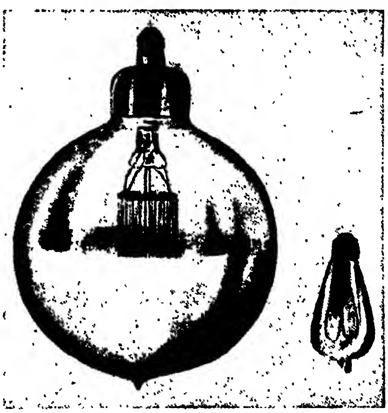
So matters were proceeding in the battle between electric light and gas light. In the meantime, however, a young Austrian man of science took up the study of the rarer earths that Lane Fox and Edison had abandoned. His name was Auer von Welsbach. Welsbach built on a discovery made in 1835 by Captain Thomas Drummond. Drummond knew that the light-giving quality of gases depended on the carbon brought to incandescence in a flame. For in the absence of carbon, as when a jet of pure hydrogen was burnt, extreme heat was produced without any light whatever. Captain Drummond introduced the needed amount of carbon into a burning jet of hydrogen, by means of a block of compressed quicklime. Thus was invented the Drummond lamp of intense limelight still used in theatres.

Now, the rare earths resemble lime in their effects upon the radiancy of gas. This was why Welsbach, in 1880, began his researches into the same strange substances as the inventors of the glow lamp had experimented with. In order to ascertain their value as illuminants, the young Austrian chemist brought to melting point one specimen after another of the rare earths on bits of platinum wire. In each case the experiment was remarkably unsuccessful. Little beads of the earths formed on the wire, and instead of improving the quality of the light the beads only dimmed it. Most men would have given up the matter on obtaining this very disappointing result, but Welsbach was inspired by his disasters; and there came into his mind an idea of that golden quality that only an inventor of genius hits on. He saw that the very thing that had made the rare earths unsuitable, when combined with the cotton filament of the electric glow lamp, would be successful in a gas burner. For in the gas flame all the carbonised cotton would be quickly burnt away, and the rare earths would remain. So he wove a mantle of cotton thread, and soaked it in a solution of one of the rare earths, and dried it and put it over a Bunsen gas burner. The cotton at once burnt away, leaving a mantle of earth that increased the light-giving quality of the gas in a wonderful manner.



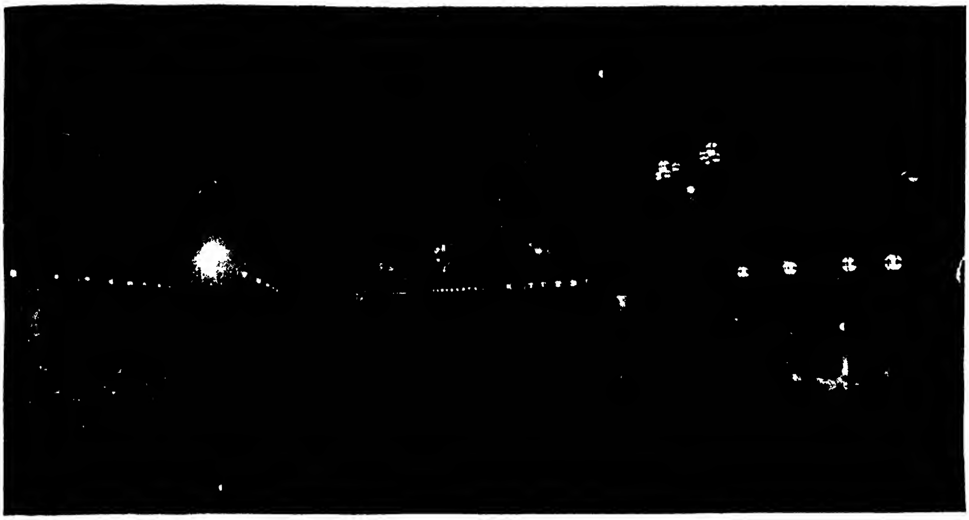
THE TUNGSTEN FILAMENT LAMPS
The left-hand lamp is the high-power lamp of former days, now replaced by that on the right, in which a longer thread of the harder tungsten is supported at the base. The centre picture is the ordinary house tungsten lamp.

The young inventor, however, had not come to the end of his troubles. His marvellous mantles crumbled to pieces in a few days; so he mixed the earth with another substance that would not fall so easily to pieces, and after six years of laborious research and experiment he made a better mantle. The extraordinary efficiency of the new means of gas lighting naturally attracted wide attention. Several companies were formed for the manufacture and sale of the mantles. In a year or two, however, all these companies were on the verge of ruin. People at first bought the mantles with eager delight; it seemed that gas had suddenly and completely triumphed over the electric filament lamp. But unhappily the mantles were still very fragile. So numerous and costly

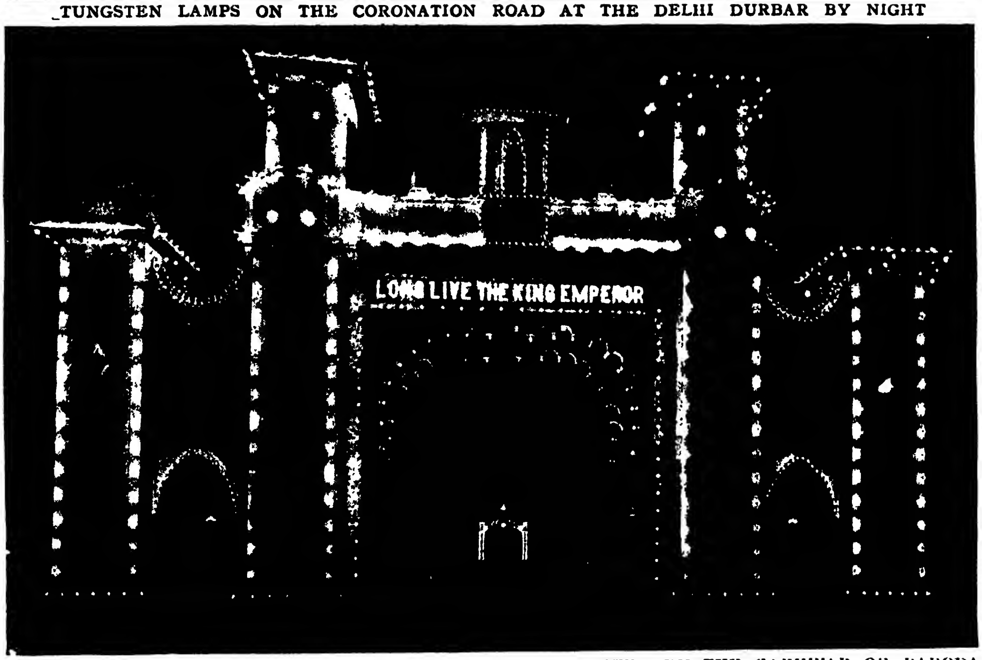


A HIGH-POWER TUNGSTEN LAMP COMPARED WITH A CARBON

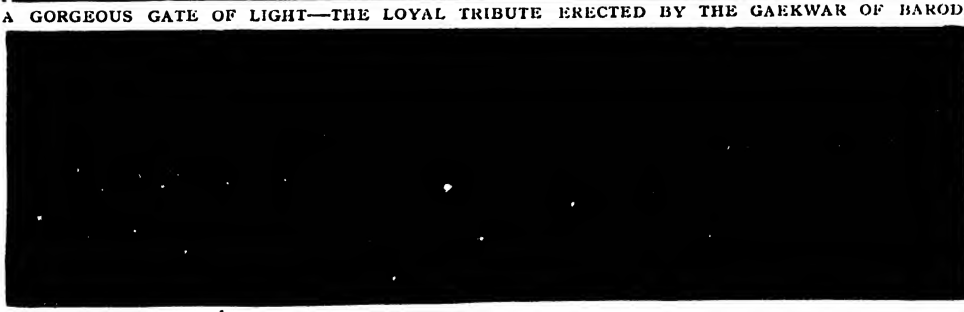
THE NEW LIGHTING IN THE NEW INDIA



TUNGSTEN LAMPS ON THE CORONATION ROAD AT THE DELHI DURBAR BY NIGHT



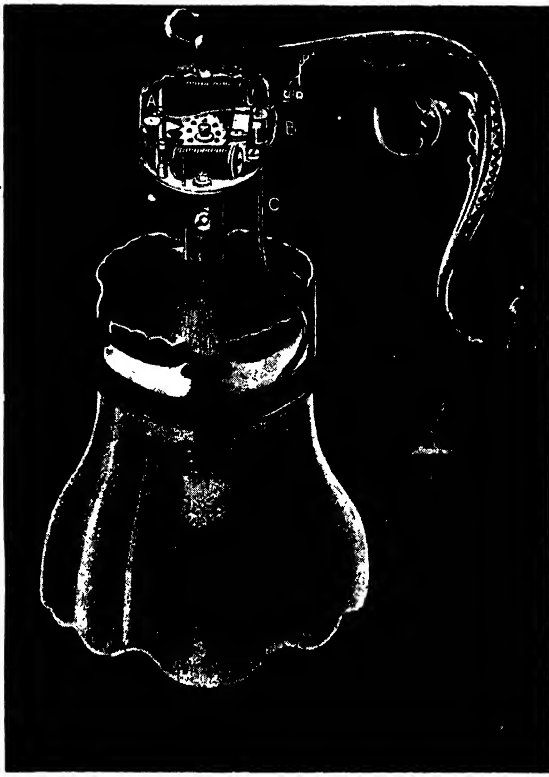
A GORGEOUS GATE OF LIGHT—THE LOYAL TRIBUTE ERECTED BY THE GAEKWAR OF BARODA



A GENERAL VIEW OF THE DURBAR CAMP BY NIGHT, LIGHTED BY TUNGSTEN LAMPS

were the breakages that the public returned to the use of the new electric light, or contented themselves with the ordinary dim but steady gas flame.

Dr. Welsbach vainly strengthened his mantle with new and stronger earths. Business did not develop, and the mantle companies thought of closing down. An accident abruptly converted them into one of the most prosperous of modern undertakings. At this time, Dr. Welsbach was using the rare earth thorium in his mantle. Going into a factory he chanced to find a bit of raw thorium oxide. He set to work on this then scarce and rare earth, in the hope that by purifying it thoroughly he would obtain a substance that would increase the light from the gas mantle. But when the purification process was completed and a mantle made of thorium, the light fell off in an unaccountable fashion. What could be the matter? It looked as though some valuable element had been cast aside in the process of purification. A series of new researches showed that it was a minute quantity of cerium which provided the valuable element.



GAS LIGHTED AND TURNED OUT BY ELECTRICITY

When the button fixed to the wall is pushed, electric current draws the bar A over to the coil, causing the ratchet to turn the cog-wheel and bring the holes over corresponding holes beneath, thus letting gas down a pipe to the mantle. At the same time a small valve (B) is raised, letting gas down the two small tubes (C). Electricity is also conveyed by the tubes to small filaments (D), which become incandescent, setting light to a small gas-jet emanating from the two small tubes. This flame ignites the gas coming through mantle. To turn the gas out, the button is again pushed. The electric current again draws the bar to the coil, and causes the ratchet to once more turn the cog-wheel so that the holes do not correspond with the holes beneath, thus cutting off the gas supply.

Here was a discovery of the highest importance. It put a new complexion on the battle between gas light and electric light. At the end of many new experiments it was found that one part of cerium and ninety-nine parts of thorium oxide were the best proportions of the earths used in the making of gas mantles. Why these proportions are the best, nobody yet knows, but the happy discovery of them in 1890 changed the fortunes of all the gas companies throughout the world. The cost of gas lighting dropped from nearly ninepence a thousand candle-hours to something well under twopence. This compared very favourably with the tenpence a thousand candle-hours of the electric glow lamp of the second class and the sixpence-halfpenny cost of the same amount of illumination from the electric lamp of the first class. Gas was victorious.

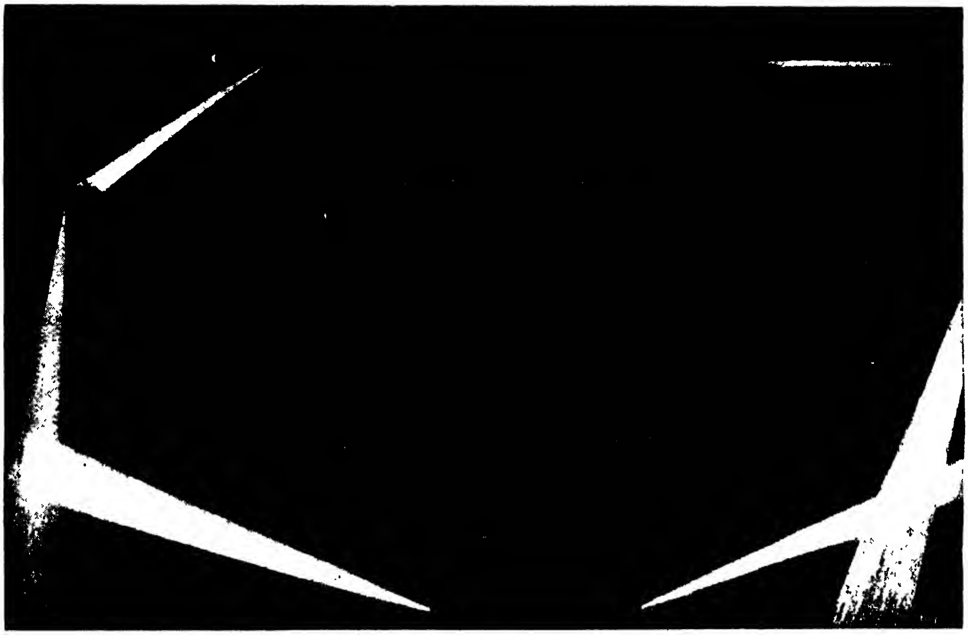
But the inventors of electric light were not idle. Indeed, Dr. Welsbach himself joined their ranks, after bringing his gas mantle to its present perfection. The problem was to find something at once stronger than the carbon filament and more resistent to the passage of electricity. It was clear that a metal was wanted. So men began to throw themselves into the study of rare metals with the same eagerness as they had pursued the study of the rare earths. Dr. Welsbach was first in the field with the osmium lamp, that was put on the market in 1904. Osmium is a rare metal found in the ores of platinum. When burnt in the ordinary way, it combines with the oxygen of the air to produce a pungent and dangerous vapour. In the vacuum of an electric bulb, however, there is no oxygen for it to combine with. The osmium lamp cut the cost of the electric light nearly in half. But—such are the vicissitudes of modern invention—the year after it was put on the market a more efficient glow lamp appeared with a filament of tantalum. Invented by Bolton, the tantalum lamp was nearly one-fifth more powerful than its rival. Then

came in 1905 the discovery of a still more efficient filament of rare metal.

Amid the waste of the Cornish tin-mines was a heavy, steel-grey substance for which no use was found. The Swedes gave it the name of "tungsten," that meant "heavy stone." This waste and apparently useless stuff has now become one of the most important things in the world. Combined with steel, it forms the cool, cutting edge of the high-speed tools—lathes, drills, planers, and so on—that work at a pace which has revolutionised the great metal industries. And now tungsten is well on the way to become one of the chief light sources of the world.

At first there was a battle for supremacy in the electric lamp between tungsten and tantalum. Tantalum used to be thought one of the hardest of metals. In his early experiments Bolton found it impossible to bore a hole through a sheet of tantalum only one-twenty-fifth of an inch thick. But by refining the metal in a powerful electric arc he reduced its strength to that of hard steel, when he was able to roll it into the thinnest of thin sheets and draw it into the finest of fine wires. By this means he was able to make a strong, wire-drawn filament; and the tantalum lamp in which it was used was more than twice as efficient as the carbon filament lamp. What was of great practical importance, its length of life was extraordinary. Moreover, rich masses of tantalum were discovered in Australia, so that the new lamp promised to become quite as cheap as the ordinary lamp.

Tungsten produced a better light than tantalum, and it was half again as efficient. It could do with one unit of electric energy what tantalum needed one and a half units to perform. But the trouble was, tungsten was so excessively hard that it could not be drawn into wire in the ordinary way. So it had to be dissolved and converted into filaments by deposition, and unfortunately the tungsten filament thus made was very fragile. The tungsten lamp was so brittle that it could not be transported over a long distance, and naturally it was liable to swift destruction even when it was fixed in a house. But this great difficulty has now been overcome. Tungsten has been drawn into wires and built into a lamp of great strength and wonderful lighting power. It produces one of the whitest lights, and it is more than three times as efficient as the ordinary electric glow lamp. By means of it the electric bulb light has been developed to something like practical perfection. All that is now needed is an abundant supply of tungsten and improved methods of manufacture to cheapen the market price of the new lamp. Already tungsten has been found in large quantities in New South Wales.



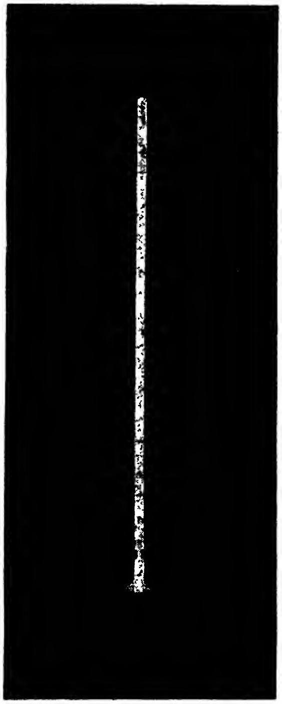
SEARCHLIGHTS AS A DEFENCE AGAINST THE WARCRAFT THAT STRIKE BY NIGHT

It is sometimes thought that the wonderful economy of the new lamp will bring about an increase in the price of the electrical current. Electric supply companies, it has been said, will have to raise their rates in order to make a reasonable profit on the diminishing consumption of electricity. We feel certain that this will not happen, at any rate in a general way. The new tungsten filament will result in a more general sale of electrical current. Now that better and cheaper electric lighting is possible, the use of the new invention will spread and the consumption of electricity will be largely increased.

It must be remembered that the electric lighting companies are still hotly engaged in the battle of illumination with the gas companies. Any increase in the price of electricity would be disastrous for the electrical interests. At present the two forces seem to us to be about equally balanced. Electricity has its advantages, gas lighting has its advantages; and not till the next invention of importance cheapens to an appreciable extent gas or electricity will the long rivalry between the two kinds of lights be decided.

The electricians certainly possess some very promising forms of lamps that need only an apparently slight improvement to come into large or even general use. The flame arc lamp, for instance, is much more efficient than either the tungsten lamp or the mantled gas burner. It gives, as we have said, light for a thousand candle-hours at the remarkable price of a halfpenny. It is based upon the oldest invention in electric lighting. In 1746 Bishop Watson produced a beautiful arch of flame between the points of a U-shaped tube, placed in a vacuum globe. In 1801 Humphry Davy made an arc between two carbon poles. Other men of science improved on these experiments, and London Bridge was lighted by electricity in 1863 on the marriage of King Edward and Queen Alexandra. But all these achievements were of real interest only to men of science.

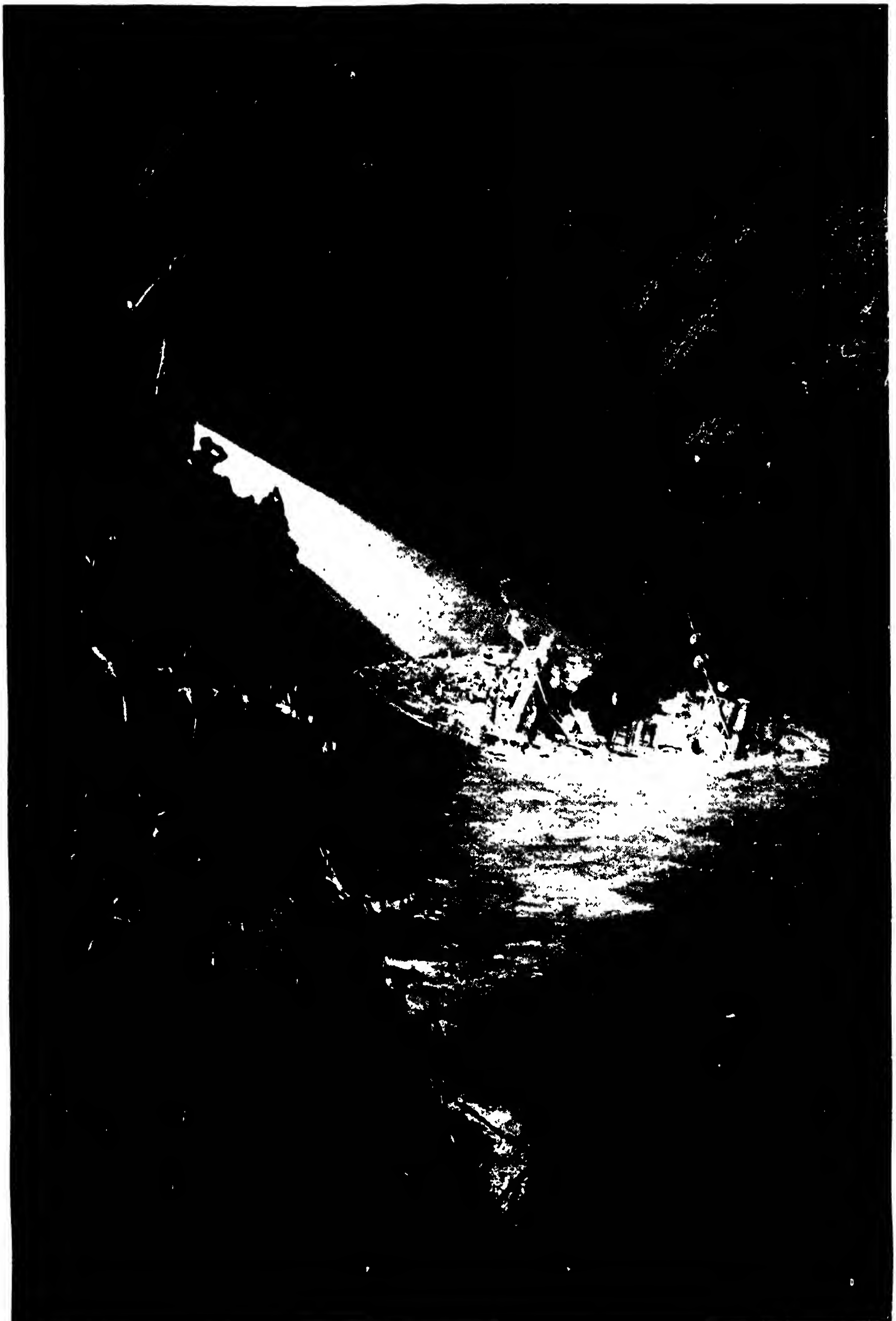
What was first required to make any kind of electric lighting practical was the invention of a means of turning mechanical energy economically into electrical powe Faraday found the principle of the dynam that does this; and in 1870 Gramm brought out his famous dynamo tha transformed electricity into one of th master-forces of civilisation. It the became easy to make electric arc lamp by sending a steady and powerful curren leaping across one carbon point to anothe carbon point. Then, by enclosing the ar in a nearly airtight inner globe, the rat of consumption of the carbon was greatl reduced, and much of the cost and labou of renewal was saved. More recently cam the invention of the flamin arc lamp. The carbons wer impregnated in preparations o lime or in the salts of certai other substances with light giving qualities. The arc the became a veritable flame o light, the radiance coming fron the arc itself, and no longe from the glowing tips. In thi way an enormous increase o light was obtained. Unfortunately, the flaming arc lam often gives off a poisonou vapour, so it is chiefly usefu in outdoor lighting.



THE ORIGINAL HEWITT MERCURY-VAPOUR LAMP

Our personal opinion is tha none of the lights that we hav discussed is the light of th future. As a matter of fact we have no idea whatever wha the light of the future will be Even its principle has not perhaps been yet discovered. Al that we know is that the glow worm and the firefly and th luminous creatures of th waters can manufacture i their own bodies a wonderfu radiance, the secret of whic science will one day reveal We rely now on incandescence as a sourc of light, often wasting in heat productio ninety-nine parts of energy in order to ge light out of the remaining one part. In Great Britain alone twenty million pound sterling is spent in manufacturing artificial light, and at least 99 per cent. of this colossal sum is absolutely thrown away on unneeded, uncomfortable, and unhealthy heat production. In other words, we get little mor than £200,000 worth of illumination at a cost of £20,000,000. Here, then, is a splendid field of activity for an invento of genius who is not averse from making an immense fortune.

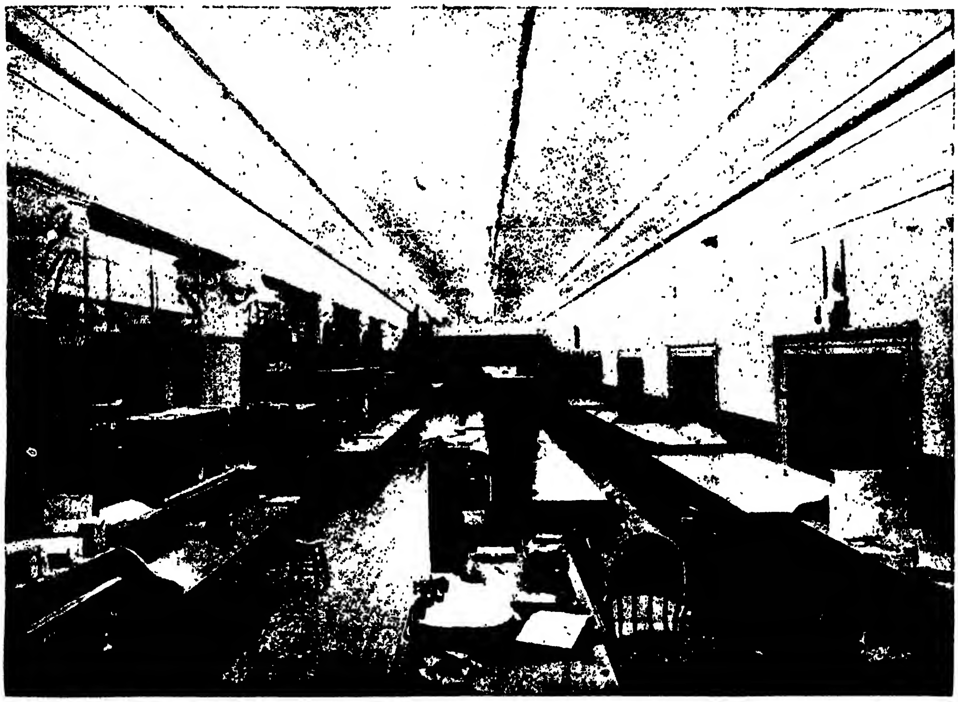
THE FIERCE LIGHT OF A BATTLESHIP



By night as well as day the big modern battleship is ready to fight, cutting away the darkness as with a sword of flame. Her searchlights scour the ocean while most of the world sleeps, and woe befall any hostile torpedo craft or destroyer that may come within its rays.

All that is needed is a practical method of producing light by the process of luminescence, instead of by the process of incandescence. The cold, beautiful light of the glow-worm and the firefly is created with the utmost economy. Their energy is turned directly into radiance, without the production of extraneous heat. In the light produced by a firefly there is only one-four-hundredth part of the heat associated with an equal amount of light created by an ordinary flame. As a manufacturer of light, the glow-worm is as efficient as the best of modern electro-dynamos, which is the most energy-saving instrument of power that man has invented. But the modern man of science seems to be gradually discovering a practical means of creating luminescence more brilliant than that of the little, flashing star with which the firefly conducts its courtship. He empties a glass tube of nearly all its air, and then sends an electric current through the vacuum tube. By this means he excites the highly rarefied gas remaining in the tube, and sets up delicate vibrations of the atoms, without having to resort to the coarser process of setting all the molecules from the gas dancing with heat. Beautiful and soft is the glow produced by the tube; and already three remarkable lighting inventions have been lately based on it.

The most wonderful of these three inventions is at present a light that only millionaires can afford. The strange new element neon, that Sir William Ramsay recently discovered in the atmosphere, is placed in a vacuum tube and excited by an electric current. The neon light is admirable; it is soft and yet brilliant, pleasing to the eyes and yet vividly clear. But as neon is at present a costly by-product, obtained in the manufacture of liquid air, it does not seem likely to come into general use. Somewhat less expensive, and yet still too dear for ordinary lighting purposes, is the beautiful artificial daylight produced by the presence of carbon dioxide in Moore's vacuum tube system. This remarkable invention is now being used in some luxurious restaurants and hotels in Berlin, but the expense of the high current of electricity necessary to produce the light prevents the Moore system from becoming popular. Yet it is said that it pays to use the tubes in silk-mills in rooms in which the delicate process of matching colours has to be carried on after sundown.

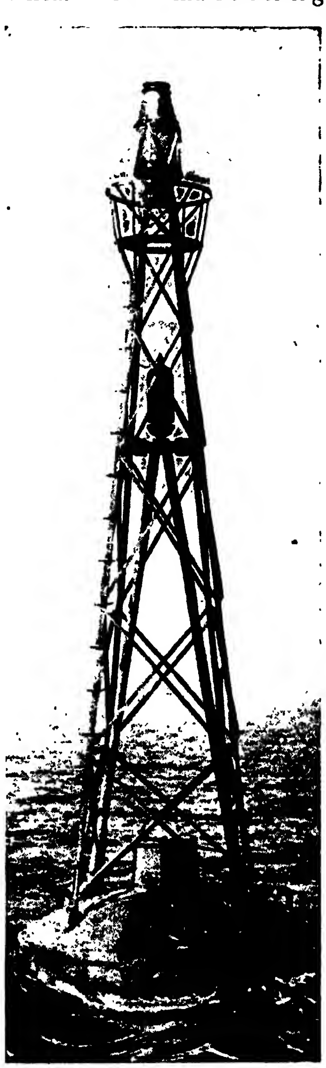


A ROOM IN THE NEW YORK POST OFFICE LIGHTED BY VACUUM TUBES

Yet we are inclined to think that even

for this purpose a cheaper form of artificial daylight is now available. For the heavy expenses of the neon and Moore vacuum tubes are avoided in the mercury tube lamp, invented, after years of research and experiment, by Mr. Peter Cooper Hewitt. The mercury lamp consists of a vacuum tube made of fused quartz or silica. In a small bulb at one end of the tube is a little mercury, which is converted by the electric current into a vapour of a peculiarly penetrating luminosity. The great thing is that the mercury is not consumed in the process of illumination; the lamp requires no attention whatever, and only a slight current of electricity is needed to keep it alight.

Mr. Hewitt brought out his mercury vapour lamp in 1902, but a strange defect prevented it from becoming popular. It was a cold light—a highly desirable thing—but not only were the heat-rays absent, but the red rays that follow next in order were also lacking. The result was, the mercury light, though very grateful to the eyes, produced a curious, unearthly effect upon everything on which it fell. The faces of the spectators lost all their shades of red and took on a pale-green colour. Another source of trouble was that there was a dangerous quantity of ultra-violet rays issuing from the new lamp. Mr. Hewitt, however, has now overcome both of these difficulties. In its latest form his lamp is fitted with a marvellous reflector that catches some of the yellow, green, and ultra-violet rays and transforms them into red rays. This is done by means of a screen coated with a curious artificial substance known as rhodamine. This substance has the extraordinary power of taking the short waves of light and lengthening them out into long waves. Then, as a considerable quantity of the invisible but dangerous ultra-violet rays still issued from the quartz tube, this tube was sheathed in a case of lead-glass, which is impervious to ultra-violet radiations. It is now possible, by combining the mercury lamp with some small tungsten lamps, to produce cheaply a clear, soft, daylight glow, easy to manufacture, healthy to work with, and wonderfully pleasant. The combination, indeed, marks the highest advance yet made in the problem of artificial light.



A FLOATING BUOY LIGHTED BY ACETYLENE GAS

By reason of its wealth of invisible ultra-violet rays, the mercury lamp is now largely used, without its protecting glass case, for medical purposes. Cheaper, more powerful, and handier than the Finsen blue light, it has a fine curative effect upon lupus and other distressing diseases. It seems very likely that when the invisible rays of the mercury lamp are carefully applied to a living organism the cells are marvellously stimulated. Mr. Cooper Hewitt some time ago took the seeds of various plants, and sowed them all under exactly the same conditions. Half were exposed to daylight and half to mercury light. The latter grew much more rapidly and luxuriantly. We referred to this fact in an early number of POPULAR SCIENCE, drawing the conclusion that the invisible ultra-violet rays were probably the force that enabled the plant to manufacture some of its products. Our remark caught the attention of one of our younger men of science, and so interested him that he has devised a special and very ingenious form of mercury lamp, by means of which he is now testing the matter from the chemical side. He is trying to transform, by the action of ultra-violet rays, certain inorganic substances into some stuffs that are created by the processes of plant life.

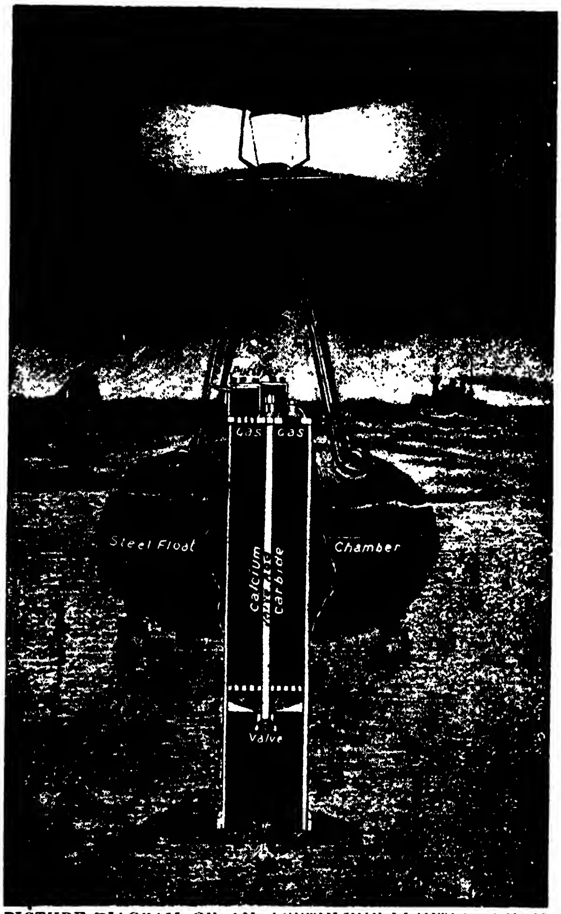
So much progress has been made in cheapening and improving the illuminating powers of coal gas and electricity that the oil lamp may seem to have no future before it. Yet there is at least one very important

lighting function in modern civilisation for which oil remains as yet unrivalled. For most of our great lighthouses use petroleum vapour to forge the mighty sword of flame with which they scatter the power of darkness and direct the voyager on his perilous way. Is it not marvellous to think that out of the primitive oil lamp of the cave-dweller science has fashioned a light that might be seen for fifty miles across the sombre midnight sea? Yet simple are the means by which this is done. An incandescent burner, using petroleum vapour with an incandescent mantle, has been found more effectual than anything else. The yellowish light so produced penetrates further through mist and fog than the glare of an electric arc lamp; and it is superior for lighthouse purposes to other new forms of illumination by reason of the ease and simplicity of its production.

In many ways a modern lighthouse is a monument of complicated science and industrial skill. Since John Smeaton, in the middle of the eighteenth century, walked through an English forest and found in the broad-based, tapering trunk of an oak the idea for a lighthouse of new design that no tempest could destroy, generations of men of scientific genius have laboured to make the ocean beacons supreme over ship-wrecking reef and blinding tempest. Long since obsolete is the system of mirrors that used to surround the guarding flame. Wonderfully designed rings of prisms now catch the rays of spreading light, and bend them and blend them into a straight intense beam of far-reaching radiance, which, if necessary, could be thrown nearly fifty miles. To effect this, the curvature of the earth must be balanced by a lighthouse a thousand feet above the waves. When this is done the petroleum vapour lamp can produce the amount of light necessary.

Practically all forms of illumination have been tried on lighthouses, from the primitive fires of the Mediterranean seafaring nations to the electric arc of recent invention. The petroleum vapour lamp survives by reason of its simplicity in handling and its trustworthiness in action. A lighthouse-keeper has so many duties to perform that any complicated machinery for light production would overtask him. Moreover, complicated machinery is liable to break down; and there is no knowing how many woeful disasters would occur if one of the principal lighthouses on a busy ocean route were extinguished even for a few hours.

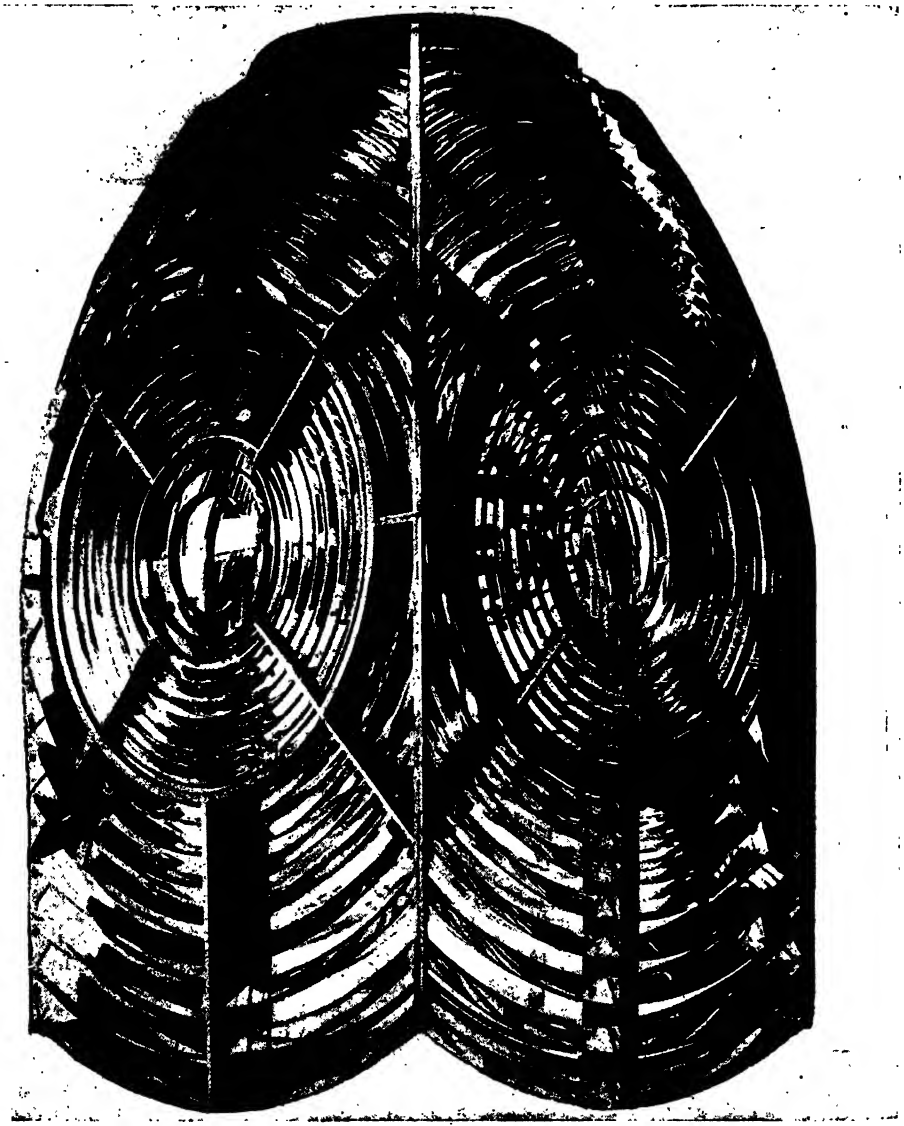
Yet there is a possibility that one of the new gases that is coming into large use for lighting purposes will be employed in the place of petroleum in lighthouses. Prior to 1895 acetylene gas was scarcely known outside chemical laboratories. In its liquid form it was fatally easy to explode, and its destructive power was equal to that of nitro-glycerine. But in 1897 Georges Claude, the inventor of the neon light, found that acetylene gas could be absorbed by a chemical obtained from wood, and stored in cylinders under considerable pressure. A few years later another Frenchman Foucher, found that,



PICTURE-DIAGRAM OF AN ACETYLENE-LIGHTED BUOY
The sea water passes through a controlling valve into a cylinder filled with calcium carbide, and combines with it to form the gas, which passes out through a purifier into the feed-tube of the lamp

by mixing the chemical from wood with charcoal or some other porous substance, compressed acetylene could be safely made for popular use. Produced from calcium carbide, at comparatively little expense, the new gas was first employed in a general way as a strong and windproof light for candle-power costs about £225 yearly to maintain, by reason of the necessity of employing a light-keeper and providing a dwelling for him. But the same amount of candle-power can be produced at a cost of £3 a year by means of stored acetylene gas.

Two years ago an acetylene lighthouse

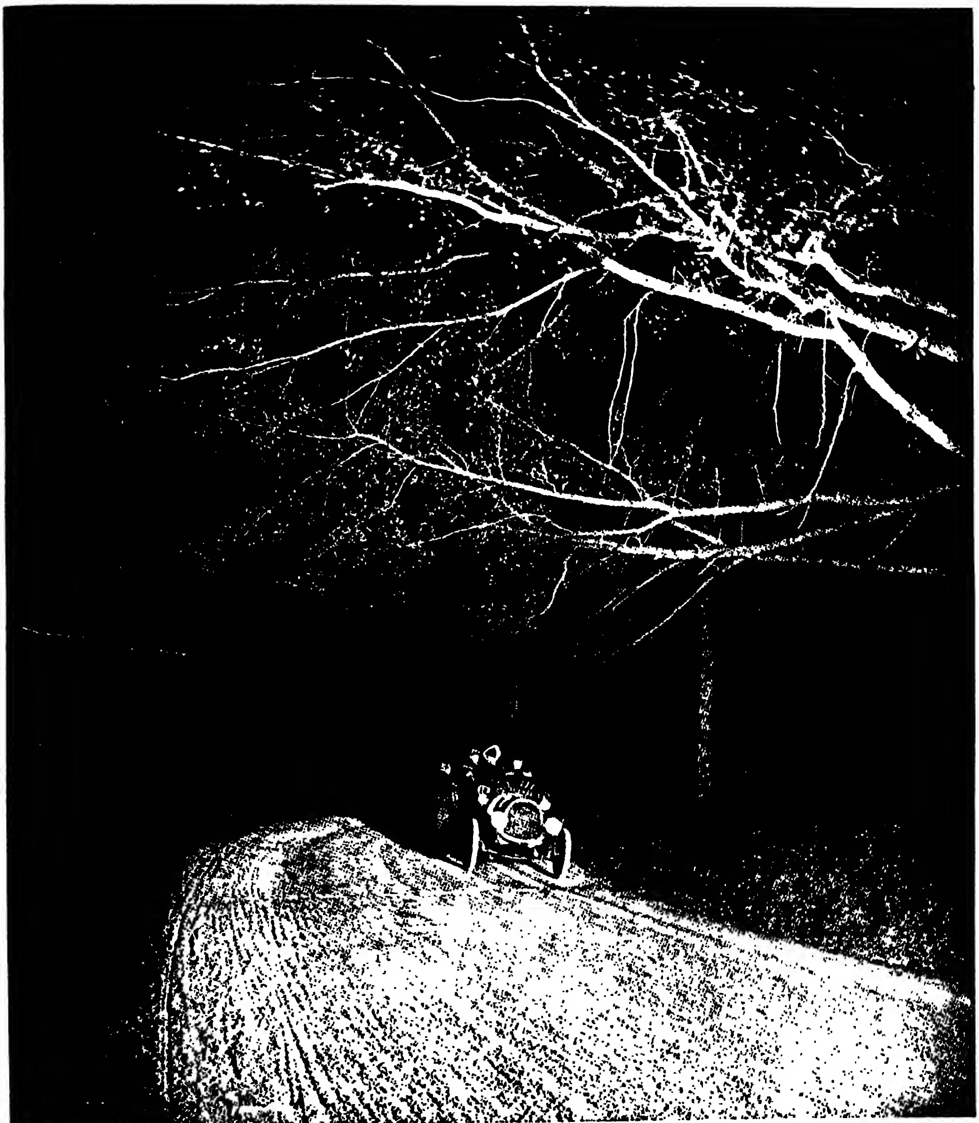


THE MANY-PRISMED LANTERN OF THE MODERN LIGHTHOUSE

bicycles and motor-cars. But as it is peculiarly suitable for various kinds of automatic lighting, it may become the universal source of all kinds of signal flames. For instance, it has been estimated that a petroleum lighthouse burner of fifty that works automatically was built a Guernsey harbour, and now some railway companies in the United States are using acetylene to light the signal lamps along their lines. At the foot of each signal i a chamber containing the compressed ga

that automatically lights two burners for several weeks without recharging. The cost is so small that the lamps are frequently allowed to burn continuously. Some railway authorities in Germany, however, have come to the conclusion that a flashing light, such as is used on many lighthouses, is vals. The new flashing signal flame is to be not only cheaper in working, but much more effective in practice than the ordinary railway signal lamp.

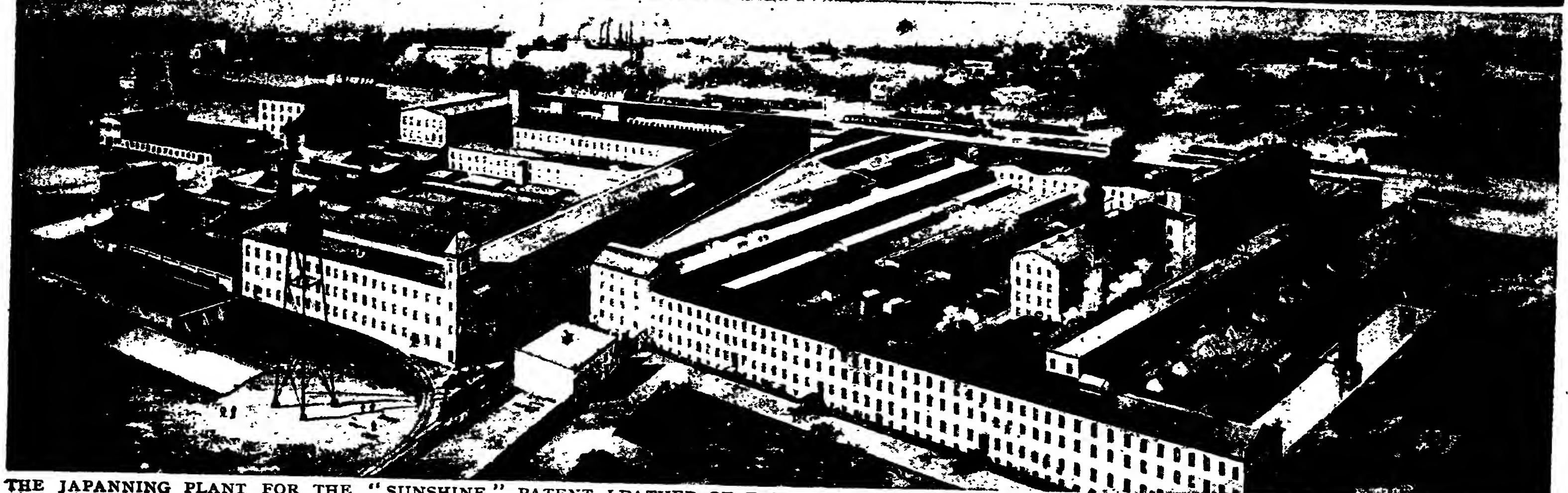
By reason of the saving of the cost in pipe-laying, compressed acetylene gas seems to be an economical source for public lighting



THE BEAUTIFUL EFFECTS OF THE ACETYLENE LIGHT ON ROADSIDE FOLIAGE

more visible and noticeable than the ordinary steady coloured flame used in railway signals. So they have devised a new kind of acetylene lamp, from which the gas passes from the receiver to the burner in slight quantity at quickly repeated inter- in small towns. Already there are over nine hundred urban communities in which the new illuminant is used for municipal lighting purposes. The acetylene light can be produced economically independently of the industrial conditions of a neighbourhood.

HUGE FACTORIES WHERE LEATHER AND KID ARE PREPARED BY RAPID CHEMICAL ACTION



THE JAPANNING PLANT FOR THE "SUNSHINE" PATENT LEATHER OF THE CORONA KID COMPANY, AT BRISTOL, PENNSYLVANIA; AND THE GIGANTIC "VICI" GLAZED KID MANUFACTORY AT FRANKFORT, NEAR PHILADELPHIA

SCIENCE AND SHOE-MAKING

The Disasters which Led to a Revolution in the Tanning Industry

RISE & FALL OF THE AMERICAN BOOT TRADE

VERY interesting and very curious, from a scientific point of view, is the present position of affairs in the leather industry. In one of our museums is the leather garment of an ancient Roman soldier which still retains somewhat of its suppleness and strength. The skin was tanned and dyed by the most unscientific of methods. On the other hand, the leather binding of many modern cheap books is carried out by the methods of modern science, but in from five to ten years the modern leather will have perished.

In most trades of the present day wonderful advantages in manufacture have been achieved by abolishing all the old rule-of-thumb ways, and calling in men of science to discover more exact, surer, and more effective methods. In the leather industry, however, we have not yet succeeded in equalling the results of the slow, primitive ways of tanning practised from four thousand years ago. Modern science has apparently failed to justify the hopes of the most enlightened of tanners. It is true that modern machinery and modern tanyards are able to produce in cheap abundance the leather goods that serve the immediate needs of the people. Things like boots and shoes and gloves, which are worn out and thrown aside in a year or two, have become greatly cheapened by scientific methods of manufacture. But, in spite of all this appearance of progress, many recent leathers count among the failures of modern science.

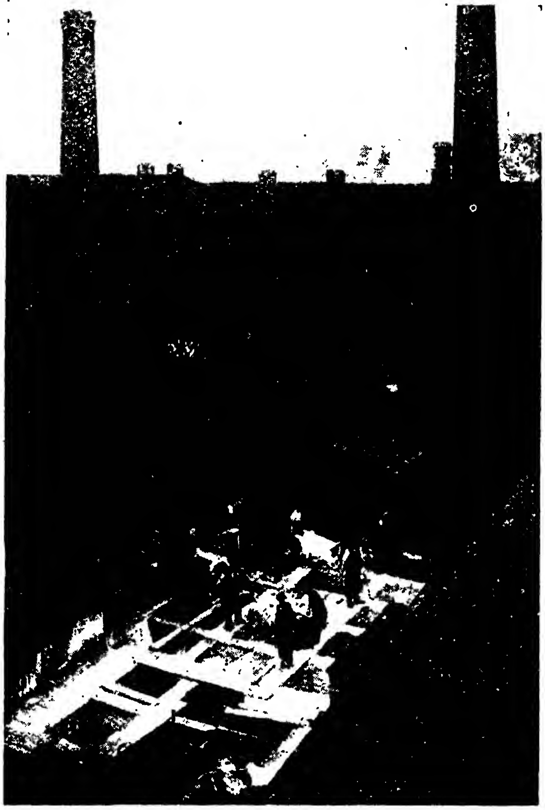
A few years ago the Royal Society of Arts appointed several committees of experts to go thoroughly into the matter. It was found that the presumably fine leather supplied to craftsmen in the bookbinding and furniture trades was deplorable. Some of it decayed in so short a period as five years. The fact is that a good deal of the leather made since 1830 is bad, and most leathers have got worse since 1860. Practically all russian bindings made during the last fifty years are rotting away; and so are morocco leathers. Hardly any good, sound calf has been made for eighty years. Ten years of life is the limit for many modern cheap leathers. Some of it loses its colour when exposed just for a week to summer sunshine. It is extremely doubtful if any of the work of the famous craftsmen in leather of our days will be known to future generations, for most of it is already perishing.

Such is the definite and authoritative verdict arrived at by well known men of science who have themselves been long and intimately connected with the leather industry. Some of these men have taken a highly important part in inventing and developing new methods of converting the perishable skins of animals into a firm, flexible, and lasting fabric. It is now fairly well known what takes place when a skin is made into leather. The under skin is the part used by the tanner. It consists of the extremely perishable substance of gelatine.

The problem of leather-making lies in discovering some matter which will combine with the gelatine fibres and preserve their flexibility, while making them strong and durable. There are three old ways of doing this. In the most primitive method oils or fats are rubbed into the skin, transforming it into a material as soft at times as fine cloth, and yet extraordinarily durable. This is the way of making chamois leather. Very likely it was known in the Stone Age, and many savages of the present day use it in an admirable manner. When, for instance, a young Zulu desires to marry a woman of his tribe, he has to make a leather robe for her with his own hands. And he dresses the skin of a large beast, now usually a cow, until he converts it into a beautifully soft and exquisite material as pleasant to the

touch as the finest and most delicate of cloths. None of the products of our modern scientific tanyards can compare with this work of a savage.

It was also the savage—possibly some Egyptian of the New Stone Age—who discovered the method of tanning leather. This is done by working into the gelatine fibres of the skin the tannin obtained from the bark or seeds or leaves of various trees and shrubs. In all probability the discovery was made accidentally while trying to dye the skin by some vegetable matter. Colour was the thing aimed at, and the marvellously preservative effects of tannin were achieved by chance. The astringent bark effected a permanent change in the texture of a skin; it kept it supple; it increased its strength, and it stopped decay. An Egyptian granite carving, probably at least four thousand years old, is preserved in the Berlin Museum in which leather-dressers are represented. One is taking a tiger skin from a tan-pit; a second is employed in another tub; while the third is working a skin upon the table. Embossed and gilt leather straps are found on some ancient mummies; and an Egyptian boat-cover of embossed goat's leather, as well as shoes of dyed and painted morocco, are still in fairly good preservation. In China, it is said, specimens of leather have been discovered in company with other relics that show them to be perhaps the oldest products of antiquity extant.



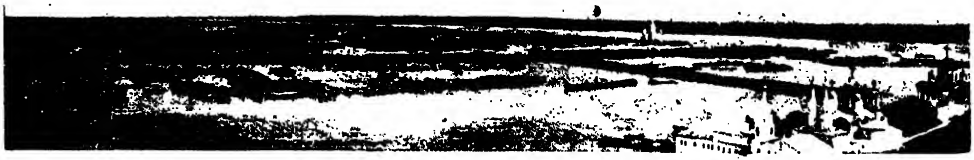
LIMING VATS AT A BERMONDSEY TANNERY

Among the Romans the third process of leather-making was practised. In this method a chemical is employed—alum. The process is now known as tawing, and it is used in the manufacture of white leather. The skins of kids and calves and lambs and sheep are tawed with alum and salt, and are then made into the upper part of kid boots and the material of gloves.

These three processes of chamoising, tanning, and tawing leather remained in universal use until about 1884. No improvement in the general methods of preparing leather took place from the primitive ages until about 1790, when the use of lime, to loosen the hair from the skin, was introduced. A few years afterwards Sir Humphry Davy apparently proved the fact that the process of tanning was a chemical art, and as such should be conducted with scientific methods. So ingenious men began to devise various ways of quickening the slow, old-fashioned rule-of-thumb processes that tanners had gradually worked out for thousands of years, and, as the Royal Society of Arts has incontestably shown, good leather gradually ceased to be produced. In about half a century from the time when Davy imported scientific ideas into one of the oldest and most useful of crafts, the chemist had cheapened leather by destroying its most valuable qualities.

The plain fact of the matter is that the men of science were wanting in knowledge. What they regarded as a fairly simple matter of chemical calculation was really a problem which was then quite beyond their powers of solving. It was largely connected with the mysterious processes of living matter. The microbe, not then suspected, much less discovered, often took an important part in helping the tanner to transform a decaying skin into a lasting piece of leather. Moreover, the matter involved the chemistry of complex

WHERE HORSES ARE BRED FOR THE TANNERY



A GENERAL VIEW OF THE FAIR GROUNDS AT NIJNI-NOVGOROD, RUSSIA

THE MARKET FOR COLT-SKINS

A 350-POUND LOAD OF SKINS

THE FIRST STAGE IN THE JOURNEY FROM RUSSIAN MART TO AMERICAN FACTORY

THE WORLD-FAMOUS CITY OF NIJNI-NOVGOROD, THE CENTRE OF THE COLT-REARING INDUSTRY

living compounds, the physics of solution and of the structure of gelatinous bodies—all of which are high and difficult provinces of knowledge that have not yet been fully conquered by the latest science.

This is why we began by saying that the present position of affairs in the leather industry was very curious and very interesting. The tanner has not received from men of science in the last hundred years the help that Sir Humphry Davy rather rashly promised. In the highest reaches of the tanner's craft, modern science has been somewhat of a will-o'-the-wisp, that has led him from the old, winding, and yet safe road, and landed him in a slough. Yet so many obstacles now prevent him from returning to the ancient track that he is compelled to trust in science to guide him further on his way. So chemist and bacteriologist and physicist are now busy endeavouring to help him. Already the invisible microbes that he used to use without knowing he was using them are being cultivated in a pure state and sent to him in bottles, so that he can employ them, measured and under scientific control, in his tanyard. Biologists are examining deeply into the wonderful structure of living matter, and especially into the action of organic membranes, and they are making such progress that they will soon be able to tell the bewildered tanner exactly what happens when he combines tannic acid with the gelatine of the stripped skin.

But it is the chemist who is foremost in helping the distracted leather-maker. This is only fair, because it was he who induced the poor man to abandon his slow but sure, primitive but effectual, methods. Many years ago Professor Knapp came to the conclusion that skin could rapidly be transformed into a good, flexible waterproof leather by the action of salts of chromium. As early as 1858 he clearly described a method of chrome tannage, but by an extraordinary oversight he did not recognise the practical value of his wonderful discovery. He thought that the leather so produced would be greatly injured by water. It was as though a man discovered a mine of diamonds and threw the stones away, thinking they were worthless pebbles.

A similar thing happened in England some years afterwards. The late Professor Hummel was asked, just as a curious experiment, to dye a piece of chrome leather that was very disagreeable in colour. In accomplishing this task, the professor discovered a new chemical tannage and produced a piece of excellent leather that is in the possession of the Yorkshire College at Leeds, and still remains in perfectly sound condition. A fortune of some millions of pounds sterling was then waiting to be picked up. Large and ancient leather industries on the Continent, employing thousands of men, were overthrown by the chemists. But no one knew it. All the master-patents of the new chemical tannage processes, on which huge businesses have recently been built up, were forestalled. But as there was no legal publication of Hummel's invention, room was left for a later inventor to rediscover the means of producing a vast revolution in the leather industry. This was done in the United States in 1884. The result was that a great American Trust was developed, which for a time dominated the whole civilised world.

REMOVING THE HAIR FROM THE LIMED SKINS BY HAND AND MACHINERY

THE CONVERSION OF PERISHABLE SKINS INTO LASTING LEATHER BY CHEMICALS

THE TUMBLERS AND PADDLE-FITTED VATS IN WHICH SKINS ARE IMPREGNATED WITH SALTS AND ACIDS IN THE CHROME TANNING PROCESS

Yet here again the event took place in an accidental way. A chemist employed by a New York firm of coal-tar colour merchants was asked by a friend if it were possible to produce a leather for covering corset-steels which would not rust the metal as all leathers prepared with alum did. Augustus Schultz, the chemist in question, knew nothing whatever about tanning processes. His happy ignorance prevented him from distrusting the evidence of his eyes. Instead of being—like Knapp and Hummel—overborne by a wide and intimate knowledge of the gaps and defects of chemical science in relation to leather-making, Schultz brought to the problem the enthusiasm excited by the new coal-tar industries. He took a chrome preparation used in making wool ready to receive an aniline dye. He treated a skin with this chrome preparation, and then put the skin in a bath of the "hypo" that photographers use. All that he really did was to repeat the successful experiment made by Hummel. The only difference was that he patented his discovery. Quickly the marvellous importance of chrome tanning was perceived in the United States. Many other American inventors at once set themselves to work out variations of the new chemical tannage, and a powerful Trust arose that acquired most of the patents. Had it not been for the previous work of Knapp and Hummel and other men of science, the Patent Tanning Company might have been able to destroy the greater part of the tanning industries, not only in America, but through all the countries of Europe.

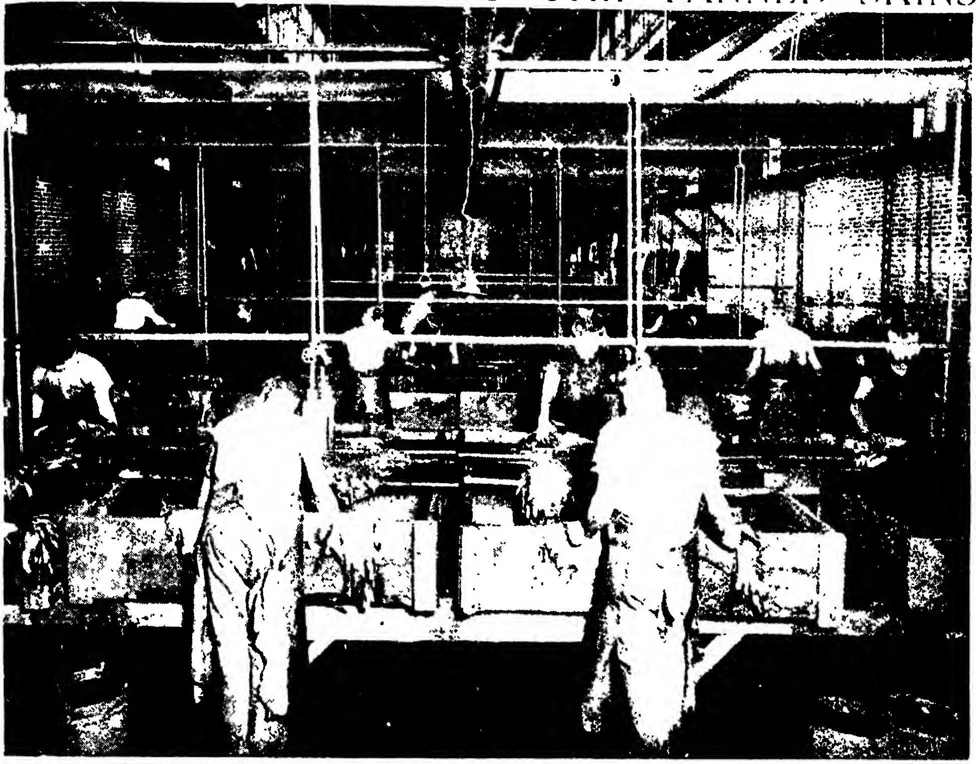
For chrome leather, far from being less resistant to water than bark-tanned skins was wonderfully strong. It was much stronger than any other leather. It could stand boiling water, that destroyed all skins prepared with alum or vegetable tans. The achievement of the technical chemists of America had far-reaching consequence on glazed kid, box and willow calf, and on the belting and harness leather industries. The French tanners of light leathers were ruined, and the Americans captured the best of the world's glazed kid trade. Wherever a goat was wandering, it was said at the time, an American was there waiting for it to die. Not only did the American possess a surprisingly cheap and rapid method of scientific tannage, but he had worked out a set of extraordinary machines for making boots and shoes out of the new leather. The only point of superiority that Great Britain maintained was in the old-fashioned tanning of strong, heavy skins for making the soles of boots. All the light leather trade was apparently lost to us, as well as to the other nations of Europe.

THE STRIKING-OUT MACHINES, THAT STRETCH AND SMOOTH THE GRAIN OF THE TANNED SKINS

So the Americans prepared to push home their advantage and capture the entire boot and shoe trade of the civilised world. A strike among our bootmakers gave them a larger opening than they expected to find; and, as is well known, they invaded our country, and established themselves here so strongly that it appeared that one of our highly important industries was well on the way to destruction.

It must be allowed that the Americans deserved the success which for a while they

COLOURING & OILING THE TANNED SKINS



THE OPERATION OF COLOURING THE TANNED SKINS BY MEANS OF DYES

INCREASING THE STRENGTH AND PLIABILITY OF LEATHER BY WORKING OIL INTO THE SKINS

obtained. Long before the invention of chrome leather, they had transformed, by their remarkable ingenuity, the ancient craft of the bootmaker and shoemaker into a mechanical industry. It was they who developed a method of providing the poorest workers of the civilised world with cheap, good, and healthy boots and shoes. Three hundred years ago, when shoemaking became a real art-craft, and the shoemaker produced beautiful works in leather and satin, which for soundness of design and beauty of shape have seldom been equalled and never surpassed, the common people profited but little by the perfection then attained. For we can still see by the pictures and etchings of the time that a large proportion of the peasantry went barefooted. What they suffered from chills and rheumatic complaints and other disabling diseases is not easily estimated.

Certainly the want of good boots was one of the causes of the general shortening of life among the working people in the damp and variable climate of Northern Europe. Some of them, it is true, were able to afford wooden shoes, which, stuffed with straw, kept their feet clear of the wet earth; and there were others that wore a foot covering of heavy leather, roughly put together and stuffed with hay. This was the brogue worn by the ancient Britons, and surviving in use in recent years in remote parts of Ireland. It resembled the mocassin of the Red Indians. But in spite of brogues and wooden shoes a considerable number of civilised people went without foot coverings, until machinery began to be employed in making sound and cheap boots.

The first piece of boot machinery, a lasting and soling machine, was made in England a hundred years ago. Our country also invented a rolling-machine that cheapened sole leather, by compressing it in a minute and saving hours of pounding. This occurred in the middle of the nineteenth century, but after that date the American inventor swept everything before him. Having made a sewing-machine, he adapted it in various ways to the quick and sound manufacture of boots and shoes, and soon other labour-saving devices were worked out in a practical way in the United States, and applied in factory productions. Then came an extraordinary stimulus to the development of all these new inventions. The American Civil War broke out, and boots were needed by the armies in vast quantities, just at the moment when the industrial energies of the nation were dissipated in warfare. This gave the machine bootmakers their opportunity, and great factories, full of machinery, sprang up and absorbed and extended the manual craft of the old bootmakers. The transformation of raw material into a finished boot requires more than a hundred manipulations, but the ingenious inventors of America at last

STAKING-MACHINES, THAT REPLACE HAND LABOUR IN MAKING TANNED SKINS SUPPLE

succeeded in devising machinery to perform practically all these operations.

The result was that the poor people in America were provided with cheap and good boots, long before the lowest classes of other civilised countries were able to afford sound foot-coverings. In ancient Egypt the rank of a person could be at once seen by looking at his feet. The rich nobility wore shoes embroidered with gold and studded with gems, and the members of each descending class displayed their position by their leather or wooden shoes and sandals. As a matter of fact, the footwear for each class was defined by law. Until a few years ago the boots worn by the various orders in our own modern society were almost as significant of the social positions of the wearers as were the shoes of the ancient Egyptians. Even a holiday crowd could easily be sorted out by looking at their boots. In the United States, however, machinery and chemical tannage gave a democratic complexion to the covered feet of the people on Sundays and festival occasions. And in cities it was difficult to see, even on working days, any difference between the shoes of a woman of means and those of a shopgirl. The clerk and his master were both fitted comfortably and gracefully by the complicated machinery working in the great boot factories, under the practical control of the firm that held the master-patents.

The American boot factory usually consisted of five departments. In the first room the sole leather was run through a machine that pared off the material to a uniform thickness, thin and ragged portions being rejected by the apparatus. The leather was then solidified in a rolling-machine, and soles were cut out of it by dies worked by a steam-hammer, or by machine-driven knives that automatically followed a pattern laid on the leather. The heels, too, were cut by means of dies, and there were various pieces of mechanism that built up the heels. The uppers of the boots, as well as the linings, were also cut by dies or machine-knives. This was the

A CORNER OF THE DRYING-ROOM FOR STAKED SKINS

weakest part of the boot machinery, for the automatic mechanism could not select the right way of the grains and the best portions of the skin.

In the stitching-room were numerous sewing-machines, driven by steam-power

A ROW OF GLAZING-MACHINES, WHICH GIVE LEATHER ITS BRIGHT APPEARANCE

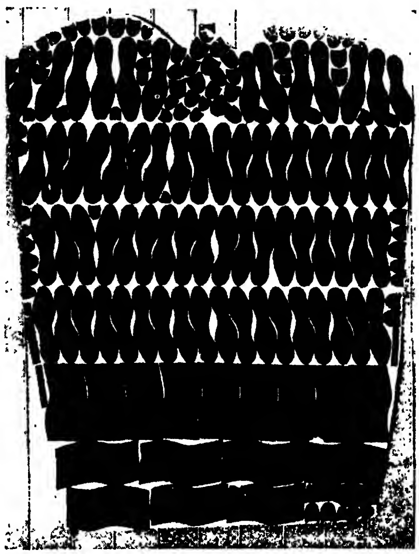
and tended by girls. Next came the bottoming-room, in which the uppers were lasted and soled and then heeled, the final shaping of the heel usually involving several operations. Then in the fifth room the final work of trimming and polishing was conducted. The trimming was done by rapidly revolving wheels, and the polishing by machine-driven burnishers, sand-paperers, and other devices. Then, if a shining surface were desired, the boot was painted with liquid polish and rubbed with a hot iron; while, if a dull finish were wanted for calf-skin, the leather was greased and rubbed with an ebony stick. In some of these factories boots were made from alligator hide and lizard, snake, and monkey skins, as well as from the commoner kinds of leather. The whole system of mechanical manufacture—now adopted with modifications throughout the civilised world—was extraordinarily ingenious and, all things considered remarkably efficient. It was a triumph of labour saving an cheapening invention.

So, armed with his latest machinery an his new chemical processes of leather making, the American sailed across th Atlantic, bent on sweeping Europe into hi bootshops. But an English chemist in tervened—Professor R. H. Procter, of th Leather Industries Department at th Yorkshire College Leeds. For some year Professor Procter ha been studying th chrome method o tanning skins. Im proving on the two bath process of Schultz he worked out a quicke one-bath method o chemical tanning. Professor Procter obtaine a good chrome tanning liquor by mixing a chromium preparatio with cane sugar an adding a little acid By this means a gree liquid was made that rapidly acted on th gelatine of a skin, and produced a sound cheap leather. Many British tanneries bega to use this new preparation, as soon as it was clearly evident that chemically mad leather of the ligh kinds would completely revolutionis a great number of some of the most important branches of the industry. A year or two afterwards, a German chemist followed Professor Procter in using can

A NEAR VIEW OF THE GLASS CYLINDER THAT GLAZES THE LEATHER

sugar or glucose in a single-bath chromium tannage, and took out a patent for it, in spite of the fact that the Englishman had anticipated him.

In the art of chemical tannage, therefore, our country recovered the ground it strangely lost when Hummel's experiment was neglected and left to the Americans to rediscover. Yet the invaders obtained a good deal of territory, especially in our large cities; and for a time American boots and shoes seemed to have ousted the plain but solid productions of Northampton and Leicester. American leather machinery was apparently invincible; and few of our general public thought that British designers of boot and shoe machinery would be able to equal the wonderful instruments that were the grand force behind the American invasion. Instead of producing a few stock sizes, the Yankee manufacturer used pattern lasts for practically every shape of foot. Small variations in width and length, and combinations of these variations, enabled him to fit every customer with a cheap boot that was almost as well moulded upon the foot as if it had been hand-made to measure. The boot trade of Britain seemed to have been destroyed.



A TANNED SKIN CUT UP FOR BOOTS

There is no waste in the boot trade; every fragment left between the shapes cut out in this picture is used in making up the heels or is worked up into a composition.

All this happened only a few years ago. But now the only monuments of the great American victory are the Yankee bootshops in London and other large cities of England, that charge a fairly good price for their goods. But in matter of fact a considerable number of these landmarks of American enterprise and industry are now directed by Englishmen in Northampton and Leicester. The American has been conquered—at least in Great Britain, though it is said he maintains a hold on France and other Continental countries. He wanted to make a fortune out of us too quickly; and while our men of science and tanners were busily but quietly outrivalling him in the chrome processes of leather-making, our machine-designers were devoting splendid energy and skill in relaying the foundations of our boot factories. So gradually the incomparable British fitter of machines constructed fine, strong, and exact factory equipments in which all that the American had done well was often done better.

And all the time there had remained in the background of the struggle a rather old-fashioned class of British tanners who had known from the beginning that England would eventually win. These men were makers of the heavy leather used for soles. They had kept to the old vegetable tannings, asking only from modern men of science that they should discover for them stronger natural astringents than those obtained from the bark of Sussex and Hampshire oak-trees. This the botanists and chemists had done, bringing to the tanyards seeds and roots and leaves from a multitude of foreign trees and plants, that enabled the tanner to increase the strength of his leathers. The tanner did not mind the slowness of his old-fashioned methods; he was content to continue making the best of strong leathers at a fairly reasonable cost. And when the people began to buy American boots he smiled and waited for the autumnal rains and the slush and snow of winter.

The fact was that the well-shaped and smart-looking American boot was weak just where it should have been strong. Its sole leather had been tanned too quickly, and in many cases the skin was poor in quality from the first. So the English boot, with its solid, well-tanned sole, won its way back to the feet of the English people. The wearers reckoned that it was not so comfortable or so smart, but they were content with its wearing qualities and its protection against chills and more serious diseases. When, however, they returned to the article of native manufacture, they were agreeably surprised.

The chemist, the machine-designer, and the last-maker had built well and quickly upon the strong and good sole leather of the old-fashioned tanner. The uppers were

THE NEW SHOEMAKING BY MACHINERY

THE MACHINES THAT CUT OUT THE SHAPES OF THE SOLE LEATHER

SOLE-ROUNDING MACHINE

CUTTING OUT UPPERS

FITTING TOGETHER UPPERS

THE MACHINES THAT SEW TOGETHER THE DIFFERENT PARTS OF THE UPPERS

The pictures on these pages are by courtesy of Messrs. Booth & Co., A. & H. Kohnstamm, Nickerson Bros., G. Whichelow, Baxter's Leather Co. J. Barlow & Sons, Freeman, Hardy & Willis, and ?. Sears & Co

made of a chrome tan skin, often taken from the yearling cattle of the East Indies. The leather was almost as lissom as kid, but it had the strength of fine calf, and the new chemical tannin made it wonderfully resistant to water. In design, the new machine-made English boot was generally equal to the higher-priced American article, and, moreover, it was to be had in a wonderful variety of "between" sizes, that enabled almost any shape of foot to be admirably fitted. Thus was one of the most formidable attacks upon a great British industry met and completely defeated. All that the American did was to wake us up. When our men were fully

THE CONSOLIDATED PULL-OVER MACHINE

aroused, they beat the invader with his own weapons; and but for his high tariff-wall they would now be flooding the American market with British leather goods both sounder and cheaper than the work of the bootmakers of Boston.

So far as can be foreseen, the only possible weapon that the American now possesses against our leather industry is that wielded for other purposes by the Chicago combination that largely controls the beef trade. This powerful Trust has a way of building new industries out of its by-products, by retaining the material and working it up in its own factories, instead of selling it to outside manufacturers. Already a large number of the skins of the South American cattle that the Trust owns or purchases are now taken to America to be made into hides. And as the Trust has an increasing command over a considerable portion of the raw material of the leather industries, it is possible that it may use this growing monopoly against all the tanners that partly depend on it for the supply of skins. Having starved the tanners out of the business, it may go on to use the leather it makes for feeding its own factories, thereby greedily acquiring the same measure of control over leather manufactures as it now possesses over the wholesale beef trade.

It thus becomes important to examine

A MACHINE THAT SEWS IN THE WELTS

into the various free supplies of skins on which the independent tanner can depend. Happily, these supplies are large, well scattered, and in no danger of being exhausted. At least, the production of skins throughout the world will not be seriously restricted until the general growth of population and the general dearth of food make cattle-breeding of every kind much less profitable and much more wasteful of land than the raising of cereal crops. This event is fortunately far distant; and by the time that it occurs men of science will have found some good substitute for leather. There are indeed rumours that this extraordinary achievement is already in a way to be

accomplished. It is said that a recent inventor has discovered a method of treating and compressing seaweed in such a manner as to produce a strong, lasting, and flexible material that has all the highly useful qualities of natural leather. So it is possible that a revolution in the leather industries of much greater importance than the discovery of chrome tannage may now be in train.

However this may be, the more immediate problem of the free supply of good hides and skins must be gone into. A great number of the sheep and cattle bred for wool and milk and meat are not of much value to the leather-maker. As a general rule, the skin of a stall-fed animal is thin and poor. And nearly all sheep that produce good wool are of little interest to the tanner. The best hides and pelts are obtained from animals exposed to all winds and temperatures, and especially from those that range at large in hilly regions and over spacious, unenclosed lands. Nearly all highly bred animals have had their meat-producing, milk-producing, or wool-bearing qualities developed at the expense of the characteristics most prized by the tanner. So we must not attribute entirely to the intervention of the man of science in the tanyard the decline in the general strength of modern leather. The stock-breeder is also partly responsible for the weakness of many hides and skins of the present day.

In Great Britain, the small hides of Scottish Shorthorns make much stronger leather than the hides of the big, beefy cattle of the South of England. So, too, the skins of Devon and Cheviot sheep, and the small sheep of the Welsh mountains, are thicker than those of the woollier and more carefully tended flocks in the rest of our country. On the Continent the cattle of the Bavarian uplands and the Pyrenees produce the finest hides; and it is from the unsheltered goats roaming the Saxon Highlands and the Alps and the Pyrenees that skins of the lightest and yet toughest grain are got.


ATTACHING THE SOLES


STITCHING ON THE SOLES


FIXING ON THE HEELS

In regard to our bootmaking trade, the kips of the yearling cattle of India and other parts of Asia are very important. A kip, we may explain, is merely the hide of a young beast. Taken from small, young cattle, and tanned by the chrome process, the kips make excellent material for the uppers of men's boots. Many of the kid boots of women, on the other hand, are now made from sheepskin, which, when tanned with chromium, produces a passable imitation of glazed kid. Very little sheepskin is nowadays sold as sheep leather, though sheep leather, when properly made, is very durable and flexible. But somehow it has gone out of fashion for practically all purposes. So the tanner converts it into various imitations of other leathers. Even the innocent little lamb masquerades as a kid in the modern leather industry, although it is difficult to see why fine, soft lamb gloves and lamb shoes cannot appear in shops under their proper names.

In the manufacture of imitation glazed kid leather, from the sheepskins imported from New Zealand and Australia, the skins are first cleaned of their natural grease by pressure or extraction, and then treated similarly to goatskins. But if the sheepskin

were tanned as a sheepskin by the old method its lasting qualities would be remarkable. There are in existence sheepskin bindings of the fifteenth century that have remained soft and flexible, but since about fifty years ago sheepskin as sheepskin is hardly to be found. It is grained in imitation of other leathers, and these imitation grained leathers are among the most perishable products of the modern tanyard. If the scientific tanner devoted himself seriously to the task of making a leather from the pelt of the sheep, in which the natural qualities of the skin were retained, the so-called kid boots and the so-called kid gloves of the cheaper sort would wear three or four times longer than they now do.

After more than three-quarters of a century of scientific experiment, the leather-making industries are still in a state of transition, and the scientific tanner has not yet been able to fulfil the promises which men of science somewhat rashly gave. To get the best kind of leather, the art-craftsmen of the present day have had to revert to primitive methods and primitive tanning materials, chief among which is sumach, a bushy shrub growing in Sicily. The Royal Society of Arts strongly recommends sumach tannage for leather required in bookbinding, furniture-covering, and other fine-art purposes. The skin is made into a bag, and the sumach tanning is poured into it. Leather properly made in this way ought to last with care for hundreds of years. On the other hand, so much progress has been recently made in the various branches of science bearing directly or indirectly on leather-making that it is probable the present stage of transition in the leather industry will soon end.

In the meantime, it would clear the air if the still good and abundant skins and hides of sheep, calves, and yearling cattle were used for what they are, instead of having their best qualities destroyed by being made into imitations of rarer leathers. In our own country, good work has been done in discovering new sources of supply in the pelts of the Arctic seals and the skin of the white whale. But why should white whale-skin be called porpoise hide, or seal leather masquerade as Levant morocco?

We do not now depend so much on leather as men did in primitive and barbaric ages. To various savages there is still nothing like leather. Of cured skins they make the tents in which they live, the shields wherewith they fight, the clothes they wear, and sometimes, as with our ancestors, their drinking-vessels are made of skin, their armour of hard leather, and their shoes of softer leather. We have gradually found better materials for many of these things. Yet leather belting is often necessary in our latest machinery. The small leather bag has recently freed women from the necessity of having pockets in their dresses. With increasing luxury, the glove, that is useful in winter, has become a social token that must be worn, or at least displayed, on the hottest summer day. The motorist has brought back the leather dress of our primitive forefathers, and his motor-car is upholstered in leather; so also is a considerable amount of modern furniture.


FINAL OPERATIONS IN BOOT-MAKING—TRIMMING AND SCOURING THE SOLES

THE MIXING OF THE RACES OF THE OLD WORLD TO MAKE THE NEW COSMOPOLITAN AMERICA

THE EMBARKATION AT LIVERPOOL OF EMIGRANTS FROM ALL PARTS OF EUROPE ON THEIR WAY TO THE UNITED STATES OF AMERICA

THE CONTEST FOR TRADE

The Growth of the Commerce of the Four Leading Nations during the Last Two Generations

TWENTIETH CENTURY ACCELERATION

At the beginning of the second decade of the twentieth century, the United Kingdom finds itself in a world in which conditions are changing with lightning speed. So rapidly are developments proceeding that a student of affairs who seeks to be well informed has to post himself with facts very closely indeed if he desires not to err in making any statement connected with actual or relative conditions. At the present day the lapse of a mere twelve months sometimes produces changes as great as were at one time recorded in ten or even twenty years. The position of an old-established commercial nation such as the United Kingdom needs, therefore, to be very closely scanned by those who are responsible for, or interested in, its continued progress.

We held in the past a position of extraordinary supremacy, which far-seeing men knew could not be indefinitely maintained. No reasonable man who looks at a map of the world, and who realises what a small area of the world's surface is included within the political boundaries of the United Kingdom, and what a small proportion of the world's population can be sustained within that area, could believe that industrial or commercial supremacy could by any human efforts be maintained by the British people. We have already seen how it was that the industrial supremacy of the United Kingdom was achieved—that it arose from applying inventive skill to a great natural source of power. We have also seen how similar sources of power placed elsewhere in the world were developed later than ours, and how, therefore, our supremacy was assailed as soon as those foreign developments proceeded. Let us now take a measure of the commercial progress of the United Kingdom, France, Germany, and the United States for a period long enough to give us a fair idea of what their relative developments have been, and of how their relative positions may yet alter.

In the tables on page 2917, the imports and exports of these four countries are set out very clearly for a period of nearly sixty years, beginning with the year 1854, in which the real values of British imports were first recorded. It is not possible to carry the records for each country so far back, but this is done whenever the facts are available. It should be understood that the import table refers solely to the imports brought into each country for home consumption, and that the export table solely refers to the exports from each country of goods that were the produce of that country. That is to say, imports brought in for subsequent re-exportation are not included in the import table, and exports of imported goods are not included in the export table.

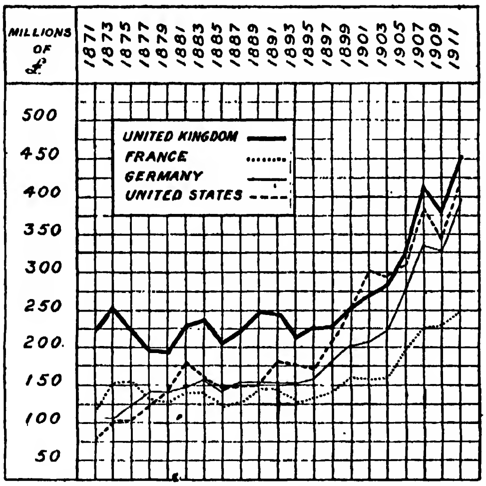
The figures given are taken partly from the publications of our own Board of Trade, and partly from the original trade returns of the countries reviewed, and they are, therefore, official in character. The figures for 1911 have not long been issued, and are preliminary figures, subject to revision. They will not be largely varied by the revision, however, and are, for the purposes of comparison, as valuable as the final figures.

There are certain differences of classification adopted by the four countries, but for the purposes of broad comparison the data are sufficiently alike to give useful results.

It is an impression of considerable progress which we derive from these significant figures. There is a very striking contrast between the opulent records of the beginning of the twentieth century, and the figures which were recorded by the Customs in the

middle of the nineteenth century. The United Kingdom has increased her imports for home consumption between 1854 and 1911 from £134,000,000 to £578,000,000, and her exports of British produce and manufactures in the same period from £97,000,000 to £454,000,000. The other three countries show a similar expansion.

It should be noticed, however, that while the record generally is one of advance all along the line, trade does not increase steadily. It oscillates even while it advances. It will be seen, further, that this is true of each individual country, whether we take British trade in the 'seventies, or French trade in the 'nineties, or American trade in the 'eighties, or German trade in the present century. We see that both imports and exports fluctuate, and proceed in cycles of alternate inflations and depressions.



PROGRESS IN EXPORTS OF FOUR NATIONS

In the accompanying diagram, lines are drawn accurately to scale showing the comparative progress of the exports of the four countries. It will be seen how the lines fluctuate, although their general tendency is in an upward direction. This ebb and flow of trade is a phenomenon with which everyone who is engaged in commerce is familiar. Nevertheless, it is doubtful whether, at any given moment of good or of bad trade, it is generally realised that the existing conditions are not permanent. We are only too familiar with the fact that, in connection with unemployment, one of the phases of which is a consequence of these fluctuations of trade, Governments are apt not to make provision for the evil in times of good trade, and to be found unprepared when, in the winter of a bad year of trade, industrial towns have thousands or tens of thousands of out-of-works on their hands. It is not our province at this stage to deal with the explanation of this phenomenon of trade fluctuation, but it may be remarked in passing that it undoubtedly arises from the lack of correlation of the factors of supply and demand throughout the world, and the consequent periodic excess of production, leading to glut and bad trade. By over-production is not here meant the production of goods beyond the needs or requirements of consumers, but production over and above what our existing civilisation enables people to buy. Herein are involved considerations of profound importance, which we shall have occasion to deal with at a later stage.

Turning from the fluctuations to the general course of the curves of trade, we see that the thick line representing British exports, which began at a much higher level than the curves of the other three countries in 1871, is also higher in 1911, but that the distance between some of them has been narrowed, and that, indeed, the export curve of the United States rose above that of the United Kingdom at the beginning of the twentieth century. In 1911 the exports of Britain, the United States, and Germany were within measurable distance of each other, but that of France has suffered a relative decline; and, indeed, it is a remarkable fact that in 1911 the British export curve is farther above that of France than it was in 1871.

The diagram refers to exports of all kinds of goods, however; and particular attention should be directed to the second half of the export table on page 2917, which shows what progress has been made by the four countries respectively in the exports of manufactured goods only, the kind of exports in which we are chiefly interested. Here we see that the United States is not only still far behind the United Kingdom as an exporter, but considerably behind Germany, and not much in advance of France.

The contrast between the progress of France and Germany is one of the most remarkable and arresting facts of the export table. If we go back to 1880, when the record of German exports of manufactures begins, we see that France and Germany started in that year very much on a level in this particular respect. Exports of manufactures by France amounted to £74 millions, and those of Germany to £82 millions. After the lapse of nearly a

IMPORTS FOR HOME CONSUMPTION, AND EXPORTS OF HOME PRODUCE, OF BRITAIN, FRANCE, GERMANY, AND THE UNITED STATES, 1854–1911 (In millions of £)

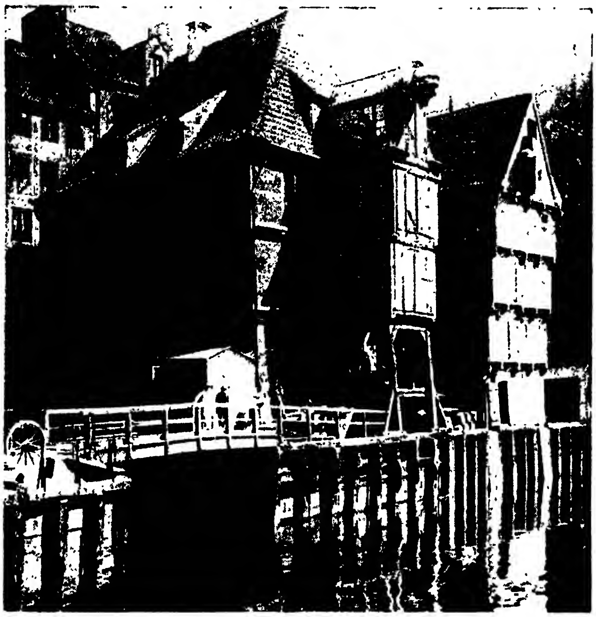
Year*	Total Imports: United Kingdom	Total Imports: France	Total Imports: Germany	Total Imports: United States	Imports of Manufactures Only: United Kingdom	Imports of Manufactures Only: France	Imports of Manufactures Only: Germany	Imports of Manufactures Only: United States
1854	134	52	Cannot be stated	57	18	Cannot be stated	Cannot be stated	Cannot be stated
1855	122	64	,,	48	16	,,	,,	,,
1856	149	80	,,	62	19	,,	,,	,,
1857	164	75	,,	69	19	,,	,,	,,
1858	141	62	,,	51	15	,,	,,	,,
1859	154	66	,,	66	19	,,	,,	,,
1860	182	76	,,	70	22	,,	,,	47
1861	182	98	,,	57	24	,,	,,	Cannot be stated
1862	183	88	,,	37	27	,,	,,	,,
1863	199	97	,,	47	28	,,	,,	,,
1864	223	101	,,	63	31	,,	,,	,,
1865	218	106	,,	44	32	,,	,,	,,
1866	245	112	,,	88	37	,,	,,	,,
1867	230	121	,,	79	37	,,	,,	,,
1868	247	132	,,	72	41	,,	,,	,,
1869	248	126	,,	82	41	,,	,,	,,
1870	259	115	,,	89	47	,,	,,	47
1871	270	143	,,	104	41	,,	,,	57
1872	296	143	,,	117	47	,,	,,	68
1873	315	142	,,	138	49	,,	,,	68
1874	312	140	,,	118	53	,,	,,	55
1875	316	141	,,	110	58	,,	,,	50
1876	319	159	,,	97	58	23	,,	41
1877	341	147	,,	92	62	22	,,	36
1878	316	167	,,	91	61	23	,,	36
1879	306	184	,,	91	57	22	,,	37
1880	348	201	139	131	65	24	38	64
1881	334	194	146	135	63	27	41	61
1882	348	193	154	149	65	31	43	70
1883	361	192	160	146	67	31	47	71
1884	327	174	160	139	63	28	45	63
1885	313	163	145	121	64	24	41	54
1886	294	168	142	130	63	23	42	60
1887	303	161	154	142	63	23	41	67
1888	324	164	162	148	70	23	43	69
1889	361	173	197	154	74	24	44	68
1890	356	177	205	162	73	26	48	72
1891	374	191	204	173	76	28	44	73
1892	359	167	198	169	76	25	42	65
1893	346	154	195	177	75	23	44	75
1894	350	154	194	132	78	22	41	47
1895	357	149	203	149	85	23	45	61
1896	386	152	212	158	92	25	46	67
1897	391	158	230	155	95	24	47	63
1898	410	179	250	124	96	25	50	47
1899	420	181	270	140	104	29	56	53
1900	460	188	283	172	110	34	59	69
1901	454	175	266	166	109	31	52	68
1902	463	176	277	183	116	31	54	78
1903	473	192	295	208	116	33	59	93
1904	481	180	313	201	116	33	60	85
1905	487	191	350	227	121	35	65	88
1906	523	225	394	250	130	40	82	108
1907	554	249	430	293	128	47	92	131
1908	513	226	377	243	120	45	79	108
1909	533	250	419	273	123	47	83	108
1910	574	287	439	324	129	57	88	136
1911	578	326	469	318	137	64	94	136

Year*	Total Exports: United Kingdom	Total Exports: France	Total Exports: Germany	Total Exports: United States	Exports of Manufactures Only: United Kingdom	Exports of Manufactures Only: France	Exports of Manufactures Only: Germany	Exports of Manufactures Only: United States
1854	97	56	Cannot be stated	45	88	Cannot be stated	Cannot be stated	7
1855	96	62	,,	40	84	,,	,,	7
1856	116	76	,,	55	102	,,	,,	8
1857	122	75	,,	58	110	,,	,,	8
1858	117	75	,,	52	105	,,	,,	8
1859	130	91	,,	58	118	,,	,,	8
1860	136	91	,,	66	124	,,	,,	10
1861	125	77	,,	43	111	,,	,,	9
1862	124	90	,,	37	111	,,	,,	7
1863	147	106	,,	39	133	,,	,,	[illegible]
1864	160	117	,,	30	146	,,	,,	16
1865	166	123	,,	28	151	,,	,,	13
1866	189	127	,,	28	173	,,	,,	11
1867	181	113	,,	58	165	,,	,,	13
1868	180	112	,,	56	163	,,	,,	13
1869	190	123	,,	57	173	,,	,,	14
1870	200	112	,,	78	181	,,	,,	15
1871	223	115	,,	89	199	,,	,,	19
1872	256	150	114	89	231	,,	,,	18
1873	255	151	112	105	227	,,	,,	21
1874	240	148	115	119	212	,,	,,	22
1875	223	155	122	104	199	,,	,,	21
1876	201	143	125	109	177	72	,,	22
1877	199	137	136	123	176	66	,,	30
1878	193	127	142	142	170	68	,,	29
1879	191	129	136	145	168	67	,,	28
1880	223	139	142	172	197	74	82	25
1881	234	142	146	184	207	75	86	28
1882	241	143	157	153	213	75	92	34
1883	240	138	161	167	211	74	96	33
1884	233	129	157	151	204	68	99	32
1885	213	123	141	151	186	65	88	31
1886	212	130	147	139	186	70	96	30
1887	222	130	154	146	194	69	101	31
1888	234	130	158	142	203	68	102	32
1889	249	148	156	152	215	77	103	35
1890	263	150	164	176	225	80	106	37
1891	247	143	156	182	210	77	101	39
1892	227	138	145	212	193	75	96	38
1893	218	129	152	173	186	70	98	37
1894	216	123	146	181	181	66	92	42
1895	226	135	163	165	192	76	107	43
1896	240	136	173	180	206	70	113	54
1897	234	144	179	215	196	77	113	65
1898	233	140	185	252	194	77	118	68
1899	255	166	207	251	210	91	133	79
1900	283	164	227	286	220	90	147	101
1901	271	160	218	304	214	90	142	97
1902	277	170	230	282	221	95	152	95
1903	286	170	247	290	230	96	161	97
1904	296	178	257	299	239	101	169	109
1905	324	195	282	311	264	110	188	127
1906	367	211	313	358	297	123	216	143
1907	416	224	[illegible]	386	332	134	236	154
1908	366	202	[illegible]	382	286	118	213	156
1909	378	229	324	341	297	128	215	139
1910	430	249	367	356	343	138	245	160
1911	451	247	398	419	362	137	265	189

* In the cases of Britain, France, and Germany, the figures are for calendar years, the American figures are for fiscal years ended June 30.

generation, we find that in 1911 the exports of manufactures by France had risen to only £137 millions, while those of Germany had increased over threefold in value, to as much as £265 millions. The value of German exports in 1911 is seen to be as high as those of the United Kingdom as recently as 1905.

It should be observed that the figures are from the official records of each country, but that the classifications by each country are not precisely the same. This, however, does not vitiate the conclusions drawn from the record of comparative progress. It is important to remember that in the long period reviewed prices have fluctuated considerably. There was a very great fall in prices down to 1895; and this partly accounts for the apparent stationariness of the trade figures for a considerable period anterior to that date. Since 1895 prices have recovered, and this partly, but by no means wholly, accounts for the increases recorded since that date.



A GERMAN TRADE LINK WITH THE PAST—HAMBURG WAREHOUSES OF THE HISTORIC HANSEATIC LEAGUE

Having made that reservation, we cannot fail to be struck with the fact that trade has been increasing recently at an ununparalleled rate. It is true that, in the early years of the table, trade made a great increase, but the increase won was upon small totals. Since 1900, on the other hand, the increase made has been upon much larger totals. The value of British exports has actually doubled since 1895, while those of Germany and the United States have more than doubled. There has certainly never been anything like this progress in the previous commercial history of the world, either of the world as a whole or of any single country in it.

Let us now pass from these general considerations to the individual cases of each of the four countries.

Dealing first with the United Kingdom the record is one of very considerable advance until the 'seventies, in which it will be seen the rate of exportation of goods slackened, while imports were not very progressive. The fact is that up to the 'seventies the United Kingdom did not encounter the competition of those countries best fitted by Nature to compete with her. Germany was still a geographical expression, and the United States had not yet acquired a sufficient population to enable her to develop her vast territory and unequalled resources. After the 'seventies, however, we see the impression made by the natural advance of Germany and America. It is not surprising that the rate of British expansion was checked. Coming to later years we see that, in the new advance of trade as a whole which has characterised the present century, the United Kingdom has played a worthy part, and that she has contrived to expand her imports and exports to totals which would have seemed incredible fifteen years ago.

France is seen to have made very considerable progress down to the date of the disastrous war with Germany. Thereafter her exports fell considerably, and, measured by value, remained almost stationary for a quarter of a century. In the advancing trade of recent years France has taken some share, but she has been unable to make anything like the advance of the United Kingdom. Her population, as we have already noted, has come to a standstill.

When we turn to German figures we get a very different record; and it is impossible not to admire the extraordinary advance which has been made in the short period for which it is possible to give the statistics of the German Empire. It was on January

18, 1871, that the King of Prussia was declared German Emperor at Versailles; and our German export record begins with 1872, and our German import record with 1880. Let us look at the following striking extract from the table.

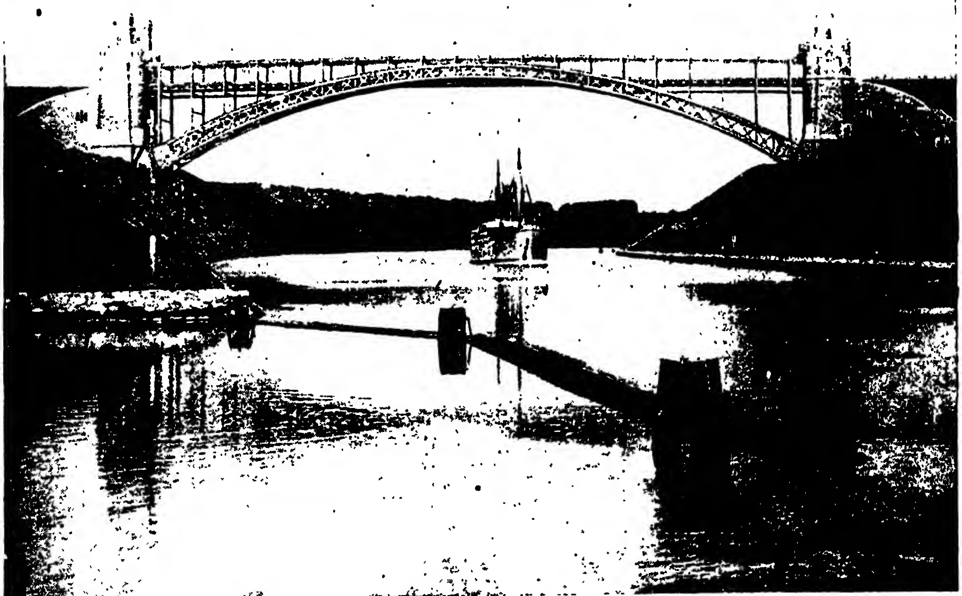
EXPORTS OF FRANCE AND GERMANY SINCE THE FRANCO-GERMAN WAR

	France	Germany
	£	£
1872	150,000,000	114,000,000
1911	247,000,000	398,000,000
Increase in 39 years	£97,000,000	£284,000,000
Approximate increase per cent.	65	250

In twenty-nine years French exports have increased by £97,000,000, or about 65 per cent.; while those of Germany have increased by £284,000,000, or about 250 per cent.

We ought not to be surprised that when once the German Empire gained internal peace, and made herself secure in the heart of Europe, she should make enormous progress. The territory which we now call the German Empire had been for nearly three centuries the scene of almost unceasing war. From the time when the terrible Thirty Years' War of 1618–1648 laid waste her towns and villages and destroyed a large part of her population, Germany had no chance to develop the arts of peace, or to show what the genius of her people could accomplish when collectively exercised. By the beginning of the eighteenth century very little recovery had been made from the horrors which had razed so many of her towns, and made desert of so much of her land. During the eighteenth century there was recovery, but Germany as a whole remained disunited, and trade between the various German principalities and powers was restricted by every device which the evil ingenuity of man could think of.

Then came the Napoleonic visitation, and the crowning humiliation of the Peace of Tilsit. We have to bear all this in mind when we are considering the backwardness of Germany, or the great advance made by the United Kingdom between the middle of the eighteenth century and the 'seventies of the nineteenth century. After the fall of Napoleon, Germany was still divided. She consisted of scores of independent large and small States, each of which had protective barriers against the others. There was no such thing as a free German home market.



GERMAN ENTERPRISE IN JOINING SEA AND SEA: A TRADING VESSEL IN THE KIEL CANAL

It was not until 1833 that Free Trade was set up between the State of Prussia and Bavaria: and at that date it is true to say that Germany had declined in commercial importance from the level at which she had attained before the outbreak of the Thirty Years' War in 1618, when the famous Hanse Towns were world-centres of trade, exhibiting a capacity for the arts of peace which had not been surpassed in the story of commerce.

In 1866 Bismarck gave Prussia the decisive victory over Austria which settled the leadership of the German peoples. Then came the Franco-German War in 1870, and the final "cementing in blood and iron." It is difficult to recall now that Napoleon III. was astonished when South Germany threw in her lot with Prussia: but recalling the fact reminds us of the differences between the Germany that is and the Germany that was. For forty years, and for forty years only, Germany has been united and able to make peaceful development within the iron ring formed by her powerful army.

Well has she used her long postponed opportunities. As we have seen in former chapters, German statesmen, with prudence and foresight, have developed the economic resources of the country by national railway and canal systems, while the personnel of the nation has been unremittingly trained, physically and mentally. National insurance has been practised for thirty years, and its effects as a crusade against disease, and as stimulating thrift and the spirit of national co-operation, are undoubted by all competent observers, whether German or foreign.

The figures of the United States are also not surprising when the facts of the case are considered. We saw in Chapter 5 how unparalleled are the natural resources which it is the good fortune of the American people to possess. The United States had not to advertise for population. Emigrants crowded to her shores: so that between natural increase and the influx of citizens from every country in the world, the 39,000,000 Americans of 1870 grew to the 95,000,000 of 1911. It is almost idle to compare the trade progress of such a country as the United States with that of either of the other countries whose records are reviewed in the tables. The conditions have been, and are, entirely different. It is only in recent years that America has begun seriously to export manufactured articles; her exports have chiefly consisted of food and materials which command markets. In 1911, however, the American exports of manufactures rose to the considerable figures of £189,000,000; and we have evidence that in the time to come the export competition of America will be as considerable and as serious as that of Germany.

If we extract for each of the four countries the exports and imports of manufactures only, for 1911, we get the following interesting facts.

EXPORTS AND IMPORTS OF MANUFACTURES BY BRITAIN, FRANCE, GERMANY AND THE UNITED STATES—1911

1.—EXPORTS

	£
Britain	362,000,000
France	137,000,000
Germany	205,000,000
United States	189,000,000

2.—IMPORTS

	£
Britain	137,000,000
France	64,000,000
Germany	94,000,000
United States	130,000,000

The United Kingdom in 1911 exported almost as many manufactures as France and Germany put together, and much more than France and the United States put together. It will also be seen that the common impression that the United Kingdom is the only large importer of manufactures is quite inaccurate. The United Kingdom and the United States import very much the same value of manufactured articles, and Germany is not far behind in this respect. Even France, which exports only £137 million worth of manufactures, imports as much as £64 million worth.

The reason for this should well be understood. As we saw in Chapter 21, when analysing British imports, commerce in manufactures very largely consists in articles which are themselves raw materials of industry, such as crude iron, steel, copper, lead, tin, zinc, finished articles which become the raw material of other trades, such as leather, paper, etc., and intermediate manufactures, such as yarn, straw plait, etc., and machinery, plant, tools, and implements. Indeed, it is the manufacturers of every country who are the chief importers of the manufactures of other countries, since in the effort to secure the best materials and plant with which to work their business economically they necessarily have occasion to draw upon other supplies than those of their own countries.

The comparisons of our table are between the United Kingdom, the head and front of the British Empire, and three other great

nations. We shall do well to remember, however, in comparing Britain with, say, Germany, that we are comparing a nation with an Empire. The comparison would, of course, be very different if we compared Empire with Empire. Germany is an Empire composed of four kingdoms, eleven duchies, seven principalities, the territory of Alsace-Lorraine, and the free ports of Hamburg, Bremen, and Lübeck. The British Empire consists of a loose congeries of kingdoms, free commonwealths, and Crown colonies, the trade statistics of which are not, as in the case of the German Empire, recorded as a whole. The healthy and growing trade statistics of the Britains Beyond the Seas exist none the less, however, and exhibit rates of expansion which are not possible in the case of the old and settled land which is the heart of the Empire.

It remains to be seen whether the centre of gravity of the British people will always be, as it now is, in the United Kingdom. The Canadians look forward with pride to the day when their vast territories will be peopled by a great race such as could not be supported under any conditions in the British Isles. Whether or not, therefore, the lapse of time sees the trade statistics of the United Kingdom occupying as magnificent a relative position as in these pages, we are entitled to hope that the statistics of the British Empire, taken as a whole, will play an even greater part in the world's commercial history than those of the United Kingdom alone have done in the past.

Nor is it necessary, treating the United Kingdom as a unit, to believe that the growth of competition of which the accompanying tables give such clear evidence is necessarily fraught with loss to the people of the British Isles. The records accompanying this chapter are evidence, it is true, of a competition which has arisen in quite recent years in the history of our country; and to the thinking man they are evidence of much more than that.

Take the export table, and consider the great development of the foreign commerce of France, Germany, and America. We see that in the short period 1900–1911 the exports of France have risen by £83,000,000, the exports of Germany by £171,000,000. and the exports of the United States by £133,000,000. And yet, with all this additional selling by these three great countries, the United Kingdom has found plenty of room to do more trade. Even while these great advances have been made by our competitors, the trade of the United Kingdom has increased by £171,000,000. Here we have convincing demonstration of the truth of the saving proposition which has been advanced in these pages—that while the United Kingdom cares to exercise skill and enterprise, it can expand its trade indefinitely, in spite of competition, because the commerce of the future will be so much greater in scale than the commerce of the past, and because the world has not yet touched the fringe of its possible developments. Nothing could be more erroneous than to regard the commerce of the world as a definite or limited thing as to which, if one nation gains, another nation must necessarily lose. If we want further evidence of this, let us look beyond the four countries already reviewed to a longer list of trading nations.

The following table shows the increase in trade which has been effected by twenty-two of the principal trading countries.

EXPORTS OF THE PRINCIPAL NATIONS COMPARED AFTER A PERIOD OF TEN YEARS

Country	1900	1911 (unless otherwise stated)	Increase
	Mill. £	Mill. £	Mill. £
United Kingdom	291	454	163
United States	285	429	144
Germany	227	398	171
France	104	247	83
Russia	76	160	84
Austria-Hungary ..	81	99	18
Italy	53	87	34
Japan	21	45	24
Denmark	16	27 (1910)	11
Norway	9	15 (1910)	6
Sweden	22	33 (1910)	11
Holland	141	218 (1910)	77
Switzerland	35	50	15
Spain	32	38	6
Roumania	11	19 (1909)	8
Egypt	17	29	12
Mexico	15	26 (1910)	11
Cuba	9	30 (1910)	21
Chile	13	24 (1910)	11
Brazil	41	63 (1910)	22
Argentine Republic	31	75 (1910)	44
China	25	51 (1910)	26

Here is further convincing evidence of the world expansion which is such an encouraging feature of the opening of the twentieth century. We are approaching an era of trade on a grand scale; and with judgment there is no reason why the people of the United Kingdom may not win from it the means to support a much larger population at a much higher standard of comfort.

CENTRES OF CIVIC PRIDE AND ARDOUR

THE TOWN HALL AT MANCHESTER, THE SECOND LARGEST CITY IN ENGLAND

THE TOWN HALL AT CARDIFF, THE PRINCIPAL TOWN OF WALES

THE IDEAL MODERN CITY

The Great Common Benefits a Municipality Should Provide, or Insist on, for the Whole of the Citizens

THINGS WE HAVE OR MAY HAVE SOON

From the day when the families of men began to live together for the sake of defence, or for co-operation in hunting or husbandry, the problems of civic government must have existed in elementary forms. The earliest community would have its internal public duties, as well as the external duties of defence, and the securing of the means of subsistence; and at every stage in advancing civilisation the growing complexity of these duties would be apparent, until now, wherever we live, the duties, rights, assistances, and restrictions of civic organisation hem us in, and, indeed, if we live in cities, become a major part of our lives. Objection to this state of things is entirely useless, for we cannot alter it. Whether we would have it so or not, we are made one family by the cement of the rates; and the most practical course open to us is to ask how we can perfect that part of our lives which is lived in common with our neighbours. Is it possible to make for ourselves an ideal city? If so, what should its characteristics be?

An ideal city can never be founded on any other bases than the intelligent idealism, foresight, and local pride of the citizens. In this respect even piety takes a second place, for knowledge, at present, is broader than piety. "Purify the hearts of your people and the city will be clean" is only a half-truth, for men may be the salt of the earth as far as personal goodness is concerned, and yet, unawares, may be, in some respects, bad citizens. Like Tennyson's village wife, they may attribute the effects of their poisonous drains to "the will of the Lord." No doubt religion, in the end, will come to see scientific evil in its true light, but at present the appeal is to ordinary, sensible citizenship.

Given that a city has the power of self-management, and values such power highly, so that all its affairs are matters of keen general interest, and presuming that its best men of business are willing to undertake the administration in a spirit of hearty local pride, then there is no reason why the city should not gradually improve itself into the position of an ideal city, supporting vigorously every institution that is necessary from either a local or a national point of view. What must be the aims that will lead to that end?

Almost with one consent, whoever talks about the management of great cities begins with health. The preservation of public health is the subject of the first paragraph in the address of nineteen would-be administrators out of twenty. And very properly so, for health, important in itself, is inextricably interwoven with almost all other subjects of high civic importance, as, for example, with education, housing, recreative exercise, transit from the crowded court to the country, and wise and adequate feeding, as well as with formal sanitation. Indeed, half, or more, of the necessities that go to the making of the ideal city might be discussed under the one heading of health.

Now, the first of all desirable things in making the ideal city is space. Unfortunately, it was only late in the day that this fact of prime importance was realised, for in many times and lands other reasons than those of health determined the building of cities. The ruling thought in many centuries was defence. The smaller the area to be defended the better, and therefore houses were crowded on a minimum of ground. Or, in hot countries, the narrow street, flanked by tall houses with overhanging roofs, gave welcome shade. Or, again, where earthquakes are not infrequent, and where houses are not built, as in Japan, so that they may fall without doing much

damage, the building often firmly binds many dwellings firmly together on arches, till they stand in blocks solid as the rock on which they rest. Each of these reasons for crowding houses on the smallest space and welding them together with firmness, with a sort of underground shade, may be seen in some Italian cities, as, for example, in the older parts of Genoa. It is true that the Romans understood the value of space in building, but the tradition left to modern times by the Middle Ages is one of restriction, and the centre of every great city has an inherited congestion that gives the limited land a tenfold value. Yet, from the point of view of health, the ideal city must have space, both as regards its general plan and its individual houses.

The Possibility of Every City Approaching the Ideal Without Ruinous Cost

So far as the older cities are concerned, central change can only come gradually through improvement schemes, on grounds of expense, the preservation of valuable sites, and respect for traditions, but town-planning arrangements are now possible everywhere in suburban areas; and indirectly they may enormously relieve central congestion, and give business space by drawing off redundant population, always provided there are rapid, ample, and cheap means of transit in and out of the city. Under these circumstances, there is no excuse for saying that any attempts to approach the ideal city are impossible. The possibility exists everywhere, and expense is not a bar. The things needed are will-power and ideas. As a matter of fact, corporate action for the improvement of a city—in proportion to its business possibilities—whether the improvement affects the business centre or the suburban residential quarters, is invariably, in the long run, a paying enterprise. The bogey of cost is only a bogey, if the scheme be well devised in view of local conditions.

Why Should Not Municipal and Private Enterprise Run in Friendly Competition?

One general consideration deserves mention before we inquire respecting the aims in detail of an ideal city in relation to health, and that is whether municipal schemes of improvement should be positive and formative on the part of a corporation, or be negative and restrictive. In other words, is the new spirit a good spirit when it leads a municipality to look ahead, to make plans, to welcome ideas, to risk something in experiment, and to say: "We will project improvements that will make some parts of this city approach the ideal a quarter of a century, or less, ahead"? Or is it better to follow the old plan, and to say: "We will leave improvement to individual enterprise and desire for gain, seeking it only by demanding, through by-laws, a minimum of efficiency. We will say: 'Houses here must conform at least to such and such dimensions, with so much open space, frontage, roadway, etc.,' and thus ensure reasonable improvement without risk"?

Probably the wisest answer to these questions may be put in the form of another question: Is there any reason why both these methods of improvement should not be adopted? Why should not an intelligently energetic municipality both improve the town, within and without, on its own account, and also offer a fair field for private enterprise to show its powers of initiation and successful accomplishment? The competition will be good in any case, and will compel all those who plan and build to give good value, without the burden of fanciful expense. Why cannot a city not only warn the remiss but show the way on its own account?

The Ideal Plan of an Unheard-of Town in the Far West

If we were to select a town-plan that most compendiously shows, in outline, what an ideal city should be, we should bring it from quite an unexpected quarter. We should go near the frontier line of Canada, where the Mormons have crossed over from the States and established one of their communities. There, on the prairie, they have built the town of Sterling. Roughly, the scheme of it is the scheme of a cart-wheel, with the streets converging, like the spokes, to a large central open space, like the hub. In the middle of this central park, which is the playing-piece of the town, stands the communal building —town hall, temple, meeting-place, concert hall, scene of social gatherings. Every street leads down to the happy playing-ground of the children, and across to the centre of all social and higher activities. Along the streets passes running water, for the town is a centre of irrigation; and the houses are separated, each with its surrounding garden-space.

Here, then, we find, evolved by a contemned sect, a town that answers fairly to the ideal for playing and pleasure spaces, and also for healthy living-spaces around, if not in, the houses; and nowhere in civilised lands is a fresh start on these

lines, on the outskirts of cities, impossible, or likely to be unremunerative.

Is it not a curious comment on the slowness of mankind, even in these supposedly headlong days, that we have not only failed to decide, save in a few conspicuous instances, what an ideal residential quarter should be like, but we have not even, after a million experiments, constructed the ideal house? Only bit by bit are we learning the essentials of house-building, and we do not yet dare to look twenty years ahead. What are the essentials made manifest since the days when the house was universally regarded as a place where each family could cower in a stuffy seclusion?

Houses, ideally, are built to admit an amplitude of air, light, and water, and to keep out damp; and they will be built, before long, to admit heat and power. In their building, too, regard should be had to work, in the kitchens; to rest, in the living-rooms; and to sickness, in one or more of the sleeping-rooms—for sickness will come. Of these needs the most immediate, no doubt, is fresh air, the least understood is light, and the most variedly useful is water, inasmuch as it is the scavenger of the house, as well as the outward cleanser and the quencher of thirst.

The Need for a Highway for Heat, as Well as for Light and Air, into Every House

It should be impossible in any city to build a house that does not have a daily bath of sunlight, an abundant flushing by a through draught of air, and an ample supply of water for drinking and baths, with water-carriage for refuse. Anything short of this means danger to the community, and an absence of the conditions which make education in health-preservation possible. Health and education, by the way, interlock at many points, and together cover nearly the whole range of social organisation.

In this country we are so hidebound by custom that we do not see immediately the need for bringing heat into our houses, by general distribution from a common centre, but the demand will prevail presently, and of course would be universally conceded in an ideal city. From no cause is there so much positive suffering as from cold during one-third at least of the English year. To the very old and the very young cold is terror and death. From it spring many of the evils of our slums. The poison of bad air is welcomed by poverty in preference to the cold, and so rooms are sealed hermetically against ventilation; the lure of the taproom is its warmth, and the chief fascination of the liquors sold there is their supposed warmth. The improvidence of the poorest with regard to food is due, in a larger degree than we suppose, to the fact that they cannot afford a fire for cooking. And yet, if heat were made centrally, in a wholesale manner, and every house were wired to receive it, as it is (or should be) piped to receive and send away water, no one need even shiver with cold or the lack of a warm meal.

The Supply of Every House with Cheap Power Sent by Wire

The piping, or wiring, of the house has now become a necessity as far as water and light (either gas or electricity or both) are concerned, and in many cases for telephonic purposes; and the probability is that the near future will see similar arrangements made not only for the distribution of heat but also of power. In one way or another the next generation will doubtless be familiar with the cheap production and distribution of power on a scale hitherto undreamed of. Not only will workshops and places of business be able to switch on an enormous pennyworth of mechanical force, but it will be available in every house where a substantial amount of work or cleaning has to be done. What will be needed from men and women will be intelligent direction of mechanical operations, and not muscular exertion. When that time comes, the necessity for packing people into crowded factories will have passed away largely, and cities may spread far and wide in the fresh air, saved from a cramped industrialism, as they have been saved from the crush demanded in the Middle Ages by self-defence.

The Unending Duty of Caring for the Sick and the Incapable

But however healthy the city may be because of its open spaces and its well-planned and fully served houses, there will still be the old need—though in diminishing proportions—for hospital accommodation for the sick and sufferers from accident, and for care on behalf of the weakly and incompetent of all ages, even when cripples have been dealt with by the Education Authorities, and the mentally defective by After-Care Committees. And this work, in an ideal city, would certainly not be left to the chance impulses of sympathetic contributors. No doubt such benevolence is very fine, as far as it goes, but it is a bulwark for the stingy, who will never pay their share until they are legally compelled.

As long ago as the "Utopia" of Sir Thomas More, spacious hospital accommodation for all sick, with the best medical attention, was devised in terms that would be acceptable today; and quite on the same level is the care of the aged whom no pension scheme can touch, and the incompetent, who abound. People who talk without knowledge of the weakness of the Poor Law system generally include in the sum of their ignorance a complete misunderstanding of the main reason why a large proportion of the inmates are "a charge on the public." It is a result of sheer incapacity. Go into any workhouse assembly of aged men, and, sitting behind them, look at their heads. A vision of inherent ineffectuality is what meets the eye. Not one in ten can ever have played a man's full part in the world of men. In our ideal city, the sick must be healed—in hospital, if their sickness is a danger to the rest of the community—and the incompetent must be sympathetically cared for; so that the hospital and something like the poorhouse will stand.

Road-paving in Cities as a Barometer of Health Statistics

One of the health conditions of the ideal city is, of course, well-paved streets. This question is usually regarded as affecting primarily the business interest of the city—rapid communication, and so forth—but it is almost equally a matter of sanitation, for the rapid and complete surface drainage of a street, impossible unless the paving is sound, is almost as important as the sewage system for carrying away impurities underneath the ground. The health statistics of any city show an instant response to improvements in street-paving—that is to say, the district that changes from being ill paved to being well paved changes also from a higher to a lower death-rate—a most significant parallelism. The most up-to-date sewage system fails in part if bad paving, or no paving, allows the upper layers of the earth to be saturated with poisons.

After health, and indeed with it in many ways, ranks education in our survey of the demands of an ideal city. An education that never ends is now regarded, happily, as a civic duty accompanying life through every stage. As has been pointed out in our Eugenics section, it certainly begins before parenthood, in view of the coming child-life. Before, at, and after motherhood the State already accepts a certain responsibility which it can only make good by giving education in child-rearing. The days of earliest infancy are now days of watchfulness in any great civic community, and the nurse-inspector is beginning to be acknowledged as a friend. By the doctoring of sickly infants, by lectures to mothers, by the provision of pure food of a suitable nature, all self-respecting cities are competing for a good record in the preservation of infant life; and the ideal city is bound to be foremost in this most important of cultures.

The Public Duty of Conserving Child-life Without Intermission

What shall happen in the post-infant days or pre-school days, when the "home-child" passes from under the surveillance of the city nurse, but has not come under the eye of the school teacher, is an unsolved problem; and one of the curses of Board of Education experiments in Memorandum legislation, some years ago, was that thousands more children had the dangerous interregnum between the cradle and the infants' class-room greatly prolonged. They were kept back out of school, to crawl for a couple more years on the doorstep or in the gutter, untrained. The ideal city will never be satisfied to lose sight, for three or four years, of its child-life. It will carry out enthusiastically the new idea of education that has come in with medical inspection of schools, and is expanded in the Children's Choice of Employments Act, when that Act is properly administered.

What is that new idea? It is not that the State shall assist in the education of the children of Brown, Jones, and Robinson, or coerce Brown, Jones, and Robinson, if need be, into allowing their children to be more or less schooled, but it is that the whole of the child-life of the nation shall be regarded in the bulk as so much invaluable material, to be registered, examined, understood, developed, physically and mentally, and trained most suitably past adolescence. What was a more or less casual parental duty becomes a national task, in which each separate city and town assists.

Scholastic Training as an Introduction to a Training for Later Life

Three times in the course of its school-life each child is numbered and physically registered, the last time being when it is passing from the schools into the workaday world. And at that time of supreme importance—if the Choice of Employments Act is properly carried out by the Educational Authorities, and not relegated to the wholly unsuitable Labour Exchanges—the teachers, parents, educational administrators, and employers will all be in consultation to fit the scholar with a suitable career, and

arrange that education shall still be carried on through continuation and technical schools, so that an apprenticeship-training may be given under public conditions. The ideal city must have within its borders and under its own management institutions for carrying on this complete training, to which the day-school life was only a scholastic introduction.

The Full Training of all Ability, to Enrich the National Life

The educational ideal of the ideal city must be to give freely to every child, according to its ability, and irrespective of its origin, a full opportunity of developing whatever powers it may be endowed with. Nothing less than that utilisation of all the latent forces of national manhood justifies a national scheme of education paid for by all. Whatever names may be given to different forms of education—secondary, technical, or university—each form of study must be open freely to all who are so gifted that they can take advantage of that form of study, and thereby be prepared to enrich the national life. The motto of the ideal city in education must be—to every scholar its full natural chance. If the facilities for this complete education are not available within a reasonable distance, they should be established. Of course, there are some dozen towns and cities of the United Kingdom where they already exist.

Outside of school or classroom work of all types, the ideal city will have many agencies and institutions that are educative in their main effects. Lectureships will exist in wide variety, appealing to all kinds of audiences. Museums will suggest and furnish facilities for lines of study; picture-galleries will give and take with other similar galleries, till a broad idea of art in its many manifestations will be presented to the citizens.

Curmudgeon Cities that Cherish their Public Pictures for their Own Sole Use

In art, happily, there are few cities that take the curmudgeon view, and try to keep their treasures to themselves, or to set up the absurd claim that the pictures they happen to possess are sufficient for the satisfaction of their citizens' inquiries and tastes. This curmudgeon view is not impossible; indeed, it exists in at least one great city, which, in other respects, almost reaches the ideal in the comprehensiveness and value of its public institutions.

Some debateable points that arise in the organisation of the ideal city are the service of books to free libraries, and the question whether a municipal theatre is desirable. In these days of universal cheap fiction, it is generally felt that, apart from the novels which are inalienable part of the literary history of the county, there is no true need for publicly provided tale-telling, and, indeed, that the provision of the novels of the hour is inimical to study of books of value and novels that have stood the test of time. Indeed, it may be questioned whether in any direction it is a duty of the community to provide amusement only. Perhaps the dividing line may be most clearly seen in the case of the theatre. The drama, which is a genuine study of life and character, and illustrates the actor's art, would take a high place in the scheme of a city's education, but on the same plane there would be no place for the frivolities of the hour that close their influence with an empty laugh. The duty of the community in this respect begins and ends with art—a distinction that is not always understood, as many a popular municipal programme proves.

The Civic Duty of Provision for Manly Exercises that Need Space

A whole set of legitimate civil enterprises may be mentioned which belong partly to the department of public health and partly to education. For example, the provision of baths is essential for the teaching of swimming even after every house is provided with a bath and abundance of water and heat. For swimming holds its own both from the points of view of health and of education. Again, parks are a border-line requirement in great cities, called for alike by health and education, and are very inadequately planned if they only keep one of these great aims in sight. The same may be said of all arrangements for drill and athletics—arrangements that might be far more vigorously developed than has been customary in the past. If we examine the commonest of taunts against the English townsman of today, it is that he prefers watching games to playing them. But does he? Is not the true explanation to be found in the fact that he has nowhere to play beyond the spaces already fully occupied? In all wise town-planning of the future a look-out must be kept for arenas for physical development.

A question that trenches on health and education and taste is: "Would an ideal city provide gardens for cultivation by those who earnestly desire them?" It may be assumed that any such provision would be free of cost to the public funds, for the gardener everywhere is willing to pay the modest price of his pleasure. It may be

said that only a small percentage of the inhabitants desire gardens, or would cultivate them in such a way as to make them an attractive sight, and that towards such a minority the rest of the community have no special duty. But is that so? It must be remembered that on the outskirts of a city it is only by municipal action that allotment gardens can be certainly arranged and kept, and even then perhaps not permanently. But any energetic corporation undertaking the full duties of city government will be sure to have land on its hands suitable for allotments—as, for example, land reserved for cemeteries—so that provision of a certain number of gardens is no risk. But behind these considerations lies the fact that many men in cities have a great desire to get back in their leisure to direct touch with the earth's fruitfulness, and take a wistful delight in the production of flowers and vegetables, so that the show from a set of allotment gardens is a sight of exceptional beauty and deep significance. It answers to a healthy primal instinct which a city may well preserve.

We have commented on the bringing into every house of an abundance of air, light, water, possibly heat, and eventually power, and of course this refers to factories, businesses, and all institutions as well as homes. That these great common needs are best provided by the community as a whole, whether efficiency or cost be the test, is universally admitted by impartial observers. It may be asked: "Why should not the municipality provide food at a price?" The answer we suggest is that there is one form of food that has a simplicity similar to air, light, and water, for it is equally natural, and there are very strong reasons why the civic authorities should provide this form of food, though all others would probably be too complex for any general handling. Of course, the food we refer to is milk.

The extension of public care to the rearing of the nation's children, through every properly equipped office of a Medical Officer of Health, has brought organised mankind face to face with the fact that milk is a simple prime necessity for the continuance of the race, and must be provided in a pure form. Indeed, it is being so provided in many a poor quarter, through the public authorities, with an extraordinarily good effect on the health of infants; and the provision of pure milk for all could be readily organised by the city, with much economy in the labour of distribution. In fact, eugenically and economically the milk trade is essentially a branch of the public health department. No other provision of food stands on the same footing, for none is so elementarily simple. There is but one milk to which all tastes must conform, whereas in every other food taste plays an enormous part in the demand, and there is no standardisation such as Nature herself provides in milk.

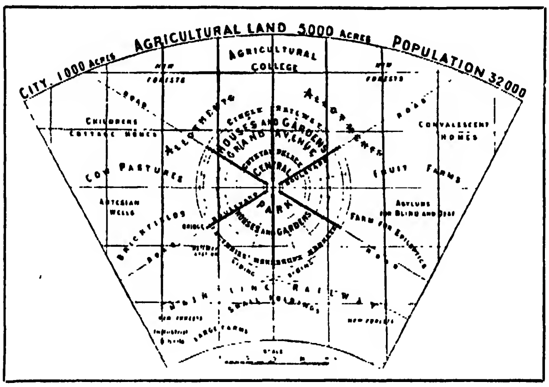


DIAGRAM OF AN IMAGINARY GARDEN CITY
From Mr. Ebenezer Howard's "Tomorrow."

Associated with the food supply is the possession and organisation of the markets, which still, in some cities, remain in private hands, though the granting of a public market was one of the earliest of the concessions made by the Crown to historic towns. The markets and market rights, however, became vested in the lords of the manor, and were traded away without reference to the public interests served by the original grant. The city that pretends to be free will own and regulate its markets, even though it has to redeem them at a great price from the private ownership into which they have drifted in less watchful days.

If we search for the real basis of the many joint duties undertaken by corporations in the name of the citizens on behalf of all, we shall find it in the care of the roads. It was the making and mending of roads that first linked men together in common action, when the need for clustering in self-defence had passed. Tithes were levied for the maintenance of the Church, the poor, and the roads and bridges. Apart from religion and philanthropy, then, the road was the first object of communal co-operation, and to the present day it gives the corporation a sort of central hold on enterprises of general utility. Thus the argument

for municipalities owning and working the tramways is strengthened by the fact that the tramway is a quicker means of doing what the road was designed to do—namely, to facilitate the passage of citizens from point to point within the area of common government—and it is enforced by the weighty consideration that whoever manages the tramways must to a large extent control the roads their making, repairs, and traffic. The same argument holds good with respect to all the wires and tubes and mains that pass under the common highway. They should be under the management of the owners of the highway: and the enterprises with which they are concerned may with general advantage be municipally owned, as by their very nature they must constitute a monopoly, for competitive opening of highways would be utterly impracticable. Competitive business, racing of wheeled vehicles along the surface of such common public roads, is bad enough. The principle underlying sound municipalisation seems to be that the community should undertake for itself all those simple, homogenous enterprises which can be definitely located, as with the bringing of wires and tubes into houses, or the passage of pipes under, or rails over roads.

FOR ONE BABY FOR ONE DAY—A SIGN OF A CITY'S CARE FOR BABYHOOD

And, this being done, one further extension of civic enterprise seems inevitable—namely, the distribution of parcels and tradesmen's wares throughout a city. If the roads and tramways are under common management, the arrangement of an errand system along all the main lines, with an immense saving in time and overlapping labour, ought not to be an impossibility. Why should there not be a timed delivery of parcels at local depots, with a saving of three-fourths of the wear and tear of tradesmen's carts?

What has been said so far of the modern ideal city—each feature already realised as practical in some instances—has been almost entirely of a material character. What about the higher products of human intercourse? In civic government has religion, for example, no formal place? What about the amenities of life, the cultivation of a sense of beauty, the inculation of pleasing manners? To this objection against the seeming exclusion of the highest concerns it may be urged that the higher influence of a wise material government is far greater than is sometimes imagined. For example, the abundant lighting of a city helps not only in the guardianship of property, but has a distinct effect on morality, and some bearing on manners. All kinds of evil thrive in the dark. Then, too, parks, museums, picture-galleries, and especially a general public use of them under conditions that exact some formality, places them under the guardianship of the public as their property, and tends to set up a high standard of carefulness and attractive behaviour. The lessons that are in the air are more potent, as a rule, than the lessons of the schools and of formal moralists.

And for that reason one of the most important considerations in the upbuilding of an ideal modern city should be the establishment of a civic centre, for social as well as administrative purposes, a town hall to which, sooner or later, every section of the community will be invited, as to a place that is theirs by general right, but that honours them by an invitation. The stimulation given to civic spirit by receptions attended by all types of citizens, the leading business men and city fathers meeting tradespeople, politicians, friendly society leaders, religious workers, and representative men and women of the rank and file of industry cannot be over-estimated. Such gatherings in the common home of the citizens, by invitation, as occasion serves, and with due formality, have effects of a far-reaching character. It is the visible sign of common citizenship, and adds dignity, responsibility, and reality to local public life.

INVINCIBLE LOVE—MANY WATERS CANNOT QUENCH IT, NEITHER CAN THE FLOODS DROWN IT

THE PAINTING "LOVE AMONG THE RUINS," BY SIR E. BURNE-JONES, A WORK DESTROYED WHILE BEING EXHIBITED, BUT AFTERWARDS RESTORED BY THE ARTIST
From the copyright photograph by Mr. Frederick Hollyer

EUGENICS AND LIBERTY

The Insufferable Lines Upon which Some Eugenists are Alienating Public Opinion

IMPOSSIBILITY OF CASTING OUT LOVE

More and more genetic knowledge is our primary need, no doubt, and further progress will soon fall to be recorded. Meanwhile, it is not too soon to face a problem which Eugenists have too lightly dealt with hitherto. Let us suppose that, in one or in a thousand respects of sufficient importance, our genetic knowledge is assured; we can definitely say, in these respects, who should or should not marry whom. That time is not yet except in very few instances, though too often we talk as if it were. But how should we proceed if we had enough knowledge and power? We have freely admitted the fundamental identity of the laws of genetics in man and the rest of the living world; we have deliberately applied to the human case the laws and methods which we learnt from the study of the pea; and perhaps we have almost thought that, once we knew enough, we could proceed with man as we do with the pea, or with any living species we choose, man alone excepted.

Here we come to a crucial division between advocates of eugenics—a division in temper, intention, and the relative values placed on different things, which is ineradicable and all-important. No ignoring of it will solve it, no talk or argument will lessen it in any degree. The opposition between those who, having the knowledge, would apply it to human breeding as to that of peas, and those who, whatever they would do, would not do that, is absolute. We had better decide where we stand before we proceed further. Men with sufficient knowledge and power are to undertake the breeding of humanity as of horses and roses; or they are not to. Let us illustrate the dilemma by very brief allusion to past proposals.

The idea that the wise few should undertake the breeding of the many is no new one. It does not need modern genetics to prove the importance of heredity in certain directions for any thoughtful observer. Lycurgus of Sparta—whom we may here assume to have been a real individual, according to tradition—clearly held and sought to practise the eugenic idea. Those days are very remote; and the no less important idea of human individuality, and the right of each person to be a person, was scarcely so much as conceivable then. The citizen was simply a constituent of the community, nation, or race, and was to be dealt with not for his own advantage or personal realisation, but for the good of the whole, present and future.

Whatever we may think of this conception of the individual, already we may begin to ask ourselves a very simple and obvious question: *How* could such an idea be practised? To this the answer is indisputable. It could be practised only in a society where this conception of the individual generally obtained. Public consent, based upon public opinion, in its turn based upon custom and tradition and the religious sanction, could alone make possible the state of things in which any Eugenist, or combination of Eugenists, however wise and well meaning, could control and decree the unions and the parenthood of the community as if men and women were peas or poultry. This clear conclusion may be deplorable or welcome, but there it is; and if we really mean our talk and study of eugenics ever to leave paper and become incarnate in flesh and blood, we had better try to decide whether we can get public opinion to assent to this course, or whether we must try some other method in the absence of that possibility.

Whatever be the truth of remote Sparta and Lycurgus, there is no doubt that Plato

existed, and wrote his famous treatise called the "Republic." This, we may remember, was to be the ideal state, in terms of a single city, for the Greeks had no idea of such vast communities as ours. Plato's "Republic" never was or will be, but his description of it, embodying, no doubt, many of the ideas of his master, Socrates, will always remain as a classic of human thought. Plato was comparatively young when he wrote it, and it bears many of the marks of youthful enthusiasm and belief in the quick setting right of things that are wrong. In later years Plato wrote his "Laws," which shows signs of a more adequate appreciation of the factor in human affairs which is called human nature, and a more chastened estimate of the power of legislation.

The Re-Echo in Our Own Time of Plato's Demand for Wisdom

Plato believed in wisdom; and before we dismiss him as a visionary, or as incompetent to teach us anything, we had better be sure that the belief in wisdom for the help of man is superfluous or needs no re-assertion today. He saw the folly and stupidity and lack of prevision with which so many men make a mess of their affairs; he deplored the defects of those in authority, just as evident then as now, when thoughtful men everywhere are in protest against the exploitation of the State by caste and politics; and he laid it down that in his Republic philosophers should be kings and kings philosophers, or, in a word, that wisdom should rule. So far, good indeed, and every Eugenist must echo Plato's contention. We believe that we already have knowledge and are daily acquiring more knowledge whereby the state of man may be advantaged, and we demand supremacy for wisdom now as Plato did then.

The Foolishness of Plato's Wisdom About the Rearing of Children

But now observe how this young bachelor proposed to proceed. The few wise were to govern for the good of the Republic, not of the Republicans. Since heredity is of such importance, only the "fit"—as modern Eugenists of this temper call them —were to be allowed to mate. "Unfit" children were to be disposed of, as in Sparta centuries before. The Republicans were, indeed, to be bred as we now breed peas. It is highly important, as Plato knew, that mothers should nurse their children, or at least that babies should be fed on human milk. The most recent French and German science is entirely with Plato there. But in his scheme of the Republic, personal feeling and prejudice and sentiment could only be disturbing factors. A baby was simply a future unit of the Republic, with certain chemical necessities which required to be met, not for its sake or its mother's sake, but for the sake of the Republic. Therefore, the mothers were to nurse the babies, but not *their* babies.

On the contrary, Plato said "we must practise every art so that no mother should know her own child." This practice was to be the cardinal point of the Republic, and "the cause of the greatest good to the city." Plato's method involved a complete community of wives and children among the guardians of the State, and on no account were the parents, of either sex, to know their children, nor the children their parents. The inferior babies were to be killed, and the rest conveyed to the common nursery of the city, where the nursing mothers were also to assemble, after the babies had been thoroughly shuffled.

Aristotle's Reply to Plato's Submergence of the Family in the Race

Thus we see that individuality, liberty, marriage, the family, the psychical aspects of fatherhood and motherhood alike, the personal element in human affairs, the love of the sexes, parental love, the parental motive for work—all these things were in the first place to be wholly destroyed, in order that the ideal State should come into being. Plato's great pupil, Aristotle, devoted the best part of his work the "Politics" to showing that the suggestions of Plato were not only wrong in themselves, but would not secure his end. As a recent commentator has said, Aristotle showed that "the destruction of the family, and the substitution in its place of one vast clan, would lead but to the destruction of warm feelings, and the substitution of a sentiment which is to them as water is to wine . . . So with the system of common marriage, as opposed to monogamy. The one encourages at best a poor and shadowy sentiment, while it denies to man the satisfaction of natural instinct and the education of family life; the other is natural and right, both because it is based on those instincts, and because it satisfies the moral nature of man, in giving him objects of permanent yet vivid interest above and beyond himself."

If we look soberly at Plato's proposals, in the light of two thousand years' experience, and our own first-hand knowledge of

human nature, we shall agree that no wise man ever made proposals so foolish. Practical eugenics will have to work on different lines from these. In the conflict eugenics versus human nature, if such a conflict there be, eugenics will certainly be broken. It can only survive by making terms with human nature, by utilising it, commanding it by obeying it, in Bacon's ever-applicable phrase.

The Injury to the Cause of Eugenics by Drastic Proposals

No one today, speaking with any authority in the name of eugenics, proposes anything so wild as Plato's "Republic." Mr. Bernard Shaw has, indeed, argued along these lines, more than once, but no one knows, himself doubtless least of all, what he really intends or desires. He is a dilettante and amateur of ideas, with which he plays in public for the delight of most of us, but which of them has his heart, or, having it, will retain it, none can say. It is therefore probably correct to say that no living Eugenist repeats Plato's proposal, at any rate as regards the abolition of marriage, the destruction of the family, the substitution of collective for individual responsibility, and the shuffling of the babies. But though that is so, the main assumption of Plato's "Republic" remains and has many representatives today. Within certain limits, to which they bow of necessity without yielding to them, these Eugenists would take mankind in hand, and decree suitable unions and forbid unsuitable ones, according to the state of knowledge existing at any time.

One initial judgment already falls to be made on those who are of this party—including the "better-dead" school in all its forms. Right or wrong in their assumptions, well or ill disposed in their intentions, it is certain that they injure the cause of eugenics in the public estimation.

The Spirit that Makes Single Believers and Thousands of Enemies

Considerable and acute recent experience in connection with the legislative proposals for dealing with the feeble-minded has only too freely illustrated the truth of this statement. Eugenists of this school gain adherents by units, but make opponents by thousands. By all means let it be granted that numbers do not constitute wisdom, and that the units who adhere to this party are people of position and standing and social advantage. That is natural. But the point to be considered is that which has already been hinted at. For the present, the question is not what ought to be or what might be, but what is, and what must be brought about if this school of Eugenists is to have its way.

The propositions here laid down are the fairly evident ones that the modern world cannot be bred according to eugenic theories without its own consent, that that consent is not at present to be had, and therefore that the first and essential task for these Eugenists is to convert public opinion to their views. They must clearly set to work and persuade the community at large, and each new generation of young people as Life produces them, that it is for their good, or for some kind of good to which they must bow, that their matings and parenthood shall be determined by the body of persons from whom these blandishments proceed. For the moment, we are not discussing the question whether the views of this party are correct. We merely assert that if they are to prevail the community must first be converted to them. Modern democracy can scarcely be bred by force and against its will; and this is indeed a case where the phrase the will of the people, so much mishandled by politicians, means something.

The Intense Unpopularity of Many Eugenic Methods

It may confidently be said that, on the whole, Eugenists are by no means successfully setting about this formidable task of theirs. The short-sightedness of too many of them is illustrated by the recent letter which Major Leonard Darwin, as President of the Eugenics Education Society, sent to "The Times." The essential clause of this letter was the statement that Eugenists do not approve of the Insurance Act, which enforces charitable contributions from the possessing classes, in the name of State Insurance. Of course, Major Darwin had no right whatever to use the word "Eugenists" in this comprehensive manner. For instance, the present writer, whose word it happens to be, heartily approves of the principle of the Insurance Act, which only needs the intelligent co-operation of well-intentioned people of all classes in order to become a magnificent instrument of national eugenics. But this unfortunate letter, which is indeed none other than a typical class-product, is important in the present connection, because it illustrates the kind of line which so many Eugenists are taking in the attempt to gain the control over the community—practically meaning control over the "working classes"—which they desire.

But every declaration of this kind prejudices eugenics and all its works. The name will soon stink in the nostrils of democracy at this rate. Already two influential organs of Liberalism in the country have been jockeyed by this sort of treatment into taking up an intensely hostile attitude towards eugenics, without any serious attempt to understand the position of those who do not conceive it as a new instrument and apology for class-dominance.

Similarly, in the House of Commons at the present time, where eugenic questions have at last come to the front in some small degree, the same difficulty exists. At the time of writing these words, Parliament and the country are considering at least two measures, one dealing with inebriates, and the other for the better care of the mentally defective. These measures and their fate will duly be considered here under the department of eugenics to which they refer. Meanwhile, the writer is having it brought home to him that you cannot get eugenic measures passed through the House of Commons by first alienating a large proportion of its most active members.

The Jealousy of Parliament for the Liberty of the Subject

For the moment, the questions of the merits of any proposals may be left out of account. The point is that, in the modern world, which is not ruled by force but by opinion, any measure that is to become law must have opinion behind it. But in the present House of Commons much opinion has been made adverse by Eugenists, as thoroughly and systematically as if that were the end they had set themselves.

Responsible members of modern legislative bodies, especially in Great Britain, with her traditions, are very rightly jealous of what they term the liberty of the subject. Their ideas about it may be chaotic and contradictory enough, and they probably would be in a state of intellectual paralysis if they were cross-examined for long upon any of the two hundred definitions of liberty. But they fear restrictive legislation, the element of compulsion, restraints upon freedom, and the kind of questioning to which their constituents will subject them unless they are careful. The reformer may find this attitude very annoying, but it is probably most salutary. It merely means that higher qualities are called for in him than if his task were merely to whisper in the ear of even a benevolent tyrant. Yet in point of fact the loudest and most conspicuously placed voices, speaking on behalf of eugenics, have lately set a number of members of Parliament against the eugenic programme, root and branch. The word has only to be mentioned now in order to rouse suspicion.

Lately, the present writer was arguing for the control of the communicable disease which destroys for ever the sight of so many babies' eyes, and his interlocutor, a member of Parliament, replied: "Well, of course, that means breeding the working classes." It means nothing of the sort; it applies to all classes, and has essentially no more to do with eugenics, as such, than has the notification of, say, mumps or ringworm; but the writer was known to be one of "those horrible Eugenists," and he could not open his mouth on behalf of cleanliness for new-born babies' eyes without being condemned.

The Injurious Opposition Between Eugenics and Social Reform

Doubtless more wisdom and discrimination might be expected from a member of Parliament, but the fact remains that Eugenists themselves are wholly to blame. The prevalent opinion of everything represented by the word "eugenics," among Liberal and Labour members of Parliament, and in the Liberal and Socialist Press with very few exceptions, is that this is a project for the control of the lower classes by a specially appointed section of the upper classes, control extending to the most intimate things of life, and offered by its advocates as a convenient substitute for everything that is usually meant by social reform. In the present writer's judgment, this opposition between eugenics and social reform is utterly unreal, and can only injure both. Many preceding chapters of this section have been devoted to showing what demands true eugenics makes for the nurture of childhood; and it is obvious that these demands cannot be granted without the making of many social reforms of a large order.

Class-domination in the Guise of Restriction of Disease

There are cases where the alternative between the two styles of eugenic procedure need not trouble us. They must be recognised now, lest we should appear to be in contradiction with ourselves when we reach the problems of negative and preventive eugenics. When a man has a horrible disease, when a girl is feeble-minded, inebriate, and erotic, no difference of opinion can exist among serious people as to our duty towards them and ourselves and the future. Such instances give a foothold to the spirit of class-domination, and the regimentation of the less fortunate. Fortified by the

ear necessity of restrictive legislation in ich cases, Eugenists may be tempted to proceed, and argue that really what we eed is to extend such measures to the ommunity at large. But to dictate to a man with a contagion, and to his harmless neighbour, are fundamentally different things. These special instances are very important; they are flagrant and urgent. But the overwhelming majority of the community have no contagious disease, and are not feeble-minded. Either eugenics must estrict its pretensions to these relatively mall though important special cases, or it nust make up its mind how to deal with he vast majority of men and women who at resent constitute the free citizens of a free community. If they present eugenic problems hat matter, how are they to be dealt with?

The Unmet Problem of Segregation for a Supposed Taint

It was pointed out here lately, in special relation to the work of the American Eugenists, that many people are liable to ransmit defects which they do not themselves display. Such a possibility is taken for granted by every student of genetics. He knows that if any human characteristic is a Mendelian recessive, persons who take this characteristic from one parent but not from the other will be what are called "impure dominants," not themselves displaying the recessive character, but transmitting it in, approximately, one-half of their germ-cells. What is to be done, then, if the character in question be objectionable or undesirable? Until within the last two or three years, Eugenists had not seen the necessity of facing the problem, and, even now, the present writer is practically alone on this side of the Atlantic in drawing attention to it. The formula has been the simple one, "segregate the unfit," and so exterminate unfitness. But now we see that this procedure, though doubtless sound and necessary in certain instances, and valuable so far as it goes, will not exterminate unfitness.

According to recent American researches which have already been discussed here, the so-called "neuropathic taint" is probably transmissible by something like 30 per cent. of the population, though the taint is actually displayed by, say, a tithe of that number at most. Of course, the quoted figure of 30 per cent. is only a first approximation. It may be much too high—though it may also be too low—and if we like we may assume that it is three times too high. Then one-tenth of the community, itself normal, is liable to transmit the neuropathic taint. There are other taints, of a parallel kind, which will involve a further fraction of the community. Are we, then, to segregate anything between one-tenth and, say, one-half of the nation? Or are we to pass laws, with their kind consent, forbidding them to marry, or to have children if they do marry, or to undergo sterilisation in early adolescence?

What Can Be Done With the Normal Person Who Transmits Defects?

These are the problems we have to face. They are not simple; and Eugenists who suppose that we can still say "Segregate the unfit," as if that settled the matter, must learn that, if we are to put an end to the insane and other deplorable tendencies, we must somehow interfere with parenthood on the part of a very considerable section of the community, the members of which are themselves normal. They certainly cannot be segregated, they certainly cannot be restrained from parenthood by any forcible means. More than that, it is difficult to envisage any means whatever for the prevention of parenthood on the part of these people which does not involve serious disadvantages and raise new problems of its own. The reader will do the argument the justice to observe that we are not yet speaking of the problem of the defective individual, but of the normal individual who is liable to transmit defect. The existence of such a person was never in the mind of the founder of eugenics, nor in that of the present writer when he included under the general question what is now known as negative eugenics. The Mendelian work that led up to the attack upon human problems on genetic lines has revealed the existence of this individual, and has even suggested that he constitutes perhaps one-third of the community. Plainly we must think again.

The Impossibility of Persuading People—Especially the Fit—to Allow Human Breeding

That is evidently a problem to which we must return under the heading of negative eugenics, and it "gives furiously to think" meanwhile. But here we are feeling our way towards positive eugenics, and similar difficulties face us. Granted that we can identify normal individuals who are not liable to transmit defect, or even individuals who will probably transmit exceptionally valuable characteristics, how are we to deal with them? Let it be at once and for all laid down here that, so far as the present writer's principles and propaganda of

eugenics are concerned, we certainly cannot *breed* these people, in any way whatever, as we breed stock or sweet-peas. These are just the people who, because of their presumable health, vigour, and individuality, will least stand our dictation. They will do as they think fit. Any proposals which involve opposite assumptions also involve the entire disruption of the bases of modern society, and the substitution therefor of something after the pattern of Plato's Republic. We do no good to eugenics or anything else by talking along these lines.

Guidance and Not Dictation the Only Rule for Eugenists

What, then, are we going to do? "Nothing," will be the answer of those who want nothing done. "Either you must breed people, or you must leave them alone." This is not the only alternative. It may be that we might begin by refraining from a thousand present forms of interference that are dysgenic; there may be room for a volume on that one project alone. It may be that public opinion is a modifiable thing, and that vast results of the most valuable kind may flow from the dissemination of knowledge and the steady preaching, in season and out of season, of the eugenic idea. In fact, that such methods produce valuable results is beyond question; only they are not conspicuous, and do not flatter the prejudices of any class or the personal vanity of any dictator. In any case, there is no other course. Even if we had the knowledge, we have not the power to breed the people; nor will they give us the power; and a people who gave us the power would not be worth breeding. If they are worth any trouble or attention at all, they must be people who will rule and direct and control themselves; and our function must be not dictation but guidance.

Galton's Reliance on Bringing Influence to Bear on Public Opinion

The embryo Eugenist may start out with different expectations and intentions, but if he is teachable he will modify them. Here are the significant words of the founder of eugenics, in his "Memories of My Life." Writing in 1908, he refers to his early writings on human heredity, which were published as long ago as 1865, and then he says: "I was too much disposed to think of marriage under some regulation, and not enough of the effects of self-interest and of social and religious sentiment." The succeeding paragraph is worth quoting: "As in most other cases of novel views, the wrong-headedness of objectors to eugenics has been curious. The most common misrepresentations now are that its methods must be altogether those of compulsory unions, as in breeding animals. It is not so. I think that stern compulsion ought to be exerted to prevent the free propagation of the stock of those who are seriously afflicted by lunacy, feeble-mindedness, habitual criminality, and pauperism, but that is quite different from compulsory marriage. How to restrain ill-omened marriages is a question by itself, whether it should be effected by seclusion, or in other ways yet to be devised that are consistent with a humane and well-informed public opinion. I cannot doubt that our democracy will ultimately refuse consent to that liberty of propagating children which is now allowed to the undesirable classes, but the populace has yet to be taught the true state of these things. A democracy cannot endure unless it be composed of able citizens; therefore it must in self-defence withstand the free introduction of degenerate stock."

Shall We Achieve Eugenics, Love Notwithstanding or Love Understanding?

Suppose that we choose our way wisely, make no mistakes, and capture public opinion. Is that instrument sufficient? The answer is that it is not. Instinct, passion, personal desires, are to be included among the rulers of the world. Here, beyond a doubt, is another weak place in the thinking of Eugenists. They have ignored love, or have forgotten it, or propose to master it. Sir Francis Galton justly showed how largely mankind consents to restrictions in marriage. Others are agreed that love can be largely directed, modified, cajoled, circumvented. One and all, they look upon it, consciously or unconsciously, as an enemy and an obstacle to eugenics. But there is another imaginable possibility, and that is eugenics through love.

This is the parting of the ways. The question is whether we are to try to achieve our positive eugenics, Love notwithstanding, or Love understanding. Here we must make up our minds. Either we must follow those who show how largely love can be avoided and circumvented, or those who believe that real love is itself eugenic and the instrument of instruments. Such there are, indeed; and the greatest of them is the veteran Swedish pioneer and thinker, Ellen Key. While genetics is working out its laws we shall do well to learn from Ellen Key how the deepest part of our nature may lead us to the highest ends.